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COMPUTER SIMULATION OF HARD ROCK TUNNELING. VOLUME II. SUPPORTING INFORMATION

R. R. Hibbard, et al

General Research Corporation

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COMPUTER SIMULATION OF HARD ROCK TUNNELING

Final Technical Report
Volume II - Supporting Information

November 1972

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13. ABSTRACT

This volume contains supporting information and further programming guides to the excavation simulation described in Volume I.

The model is implemented in FORTRAN 4 for CDC 6000 Series Computers. A computer source tape is available from NTIS.

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FOREWORD

This volume contains supporting information and further programming guides to the excavation simulation described in Volume I.

The coordination of the material in Volume II was done by R. R. Hibbard and L. M. Pietrzak. The author credits are as follows:

Appendix I:	D. S. Hyman	(Geological Surveying and Prediction)
Appendix II:	F. H. Murphy	(Geology Model)
Appendix III:	P. K. Parish	(Programs TUNNEL and GENTNL)
Appendix IV:	M. McJunkin F. H. Murphy B. H. Lieu	(Excavation Model)
Appendix V:	L. M. Pietrzak W. R. Thomson	(Layout Tunnel Data)

INDEX OF SUBROUTINES

NOTE: For any subroutine, a subroutine name in parentheses beside it indicates the routines are identical. A subroutine name in parentheses below it indicates the subroutine's normal entry point if it has both a normal and initialization entry point.

Preceding page blank

INDEX OF SUBROUTINES (Cont.)

INDEX OF SUBROUTINES (Cont.)

APPENDIX I

GEOLOGICAL SURVEYING AND PREDICTION

by

D. S. Hyman

SUMMARY

This study discusses the significance of the knowledge of geological conditions to a tunneling project and briefly describes those measurement techniques and procedures that are in general use for geological surveying and prediction.

CONTENTS

I. INTRODUCTION

It is generally recognized that the geological (and hydrological) conditions more than any other factor determine the degree of difficulty and the cost of a given tunnel project. This is easy to see, since the tunneling system, support and liner design, and total system performance are a direct and strong function of the geologic medium to be tunneled through. In essence, the latter is truly a key variable in the total economic picture of a project. As a result, geologic exploration and prediction techniques have a very important influence on the planning, design, and performance of an excavation system. Although it is not yet possible to identify a return-on-investment relationship for geological exploration it is clear that a more accurate knowledge of geological conditions will permit considerable savings from the improved planning and design of a project.

At present, less than 2% of the total project cost is generally allocated to pre-excavation geological investigations.[1,2] This probably reflects the fact that the scope and extent of the geological survey is a compromise between technical desirability and economic feasibility. Moreover, the point of compromise may not be reached objectively in many instances. Budgetary considerations of sponsoring agencies, political considerations, etc., may also play a role in the decision process. In addition, no comparative estimates for total project cost versus the geological investigation investment has ever been made, and even if they had, considerable doubt about the validity of the comparison would remain since it is never possible to "excavate again, this time with more geological information." However, some indications of the significant and perhaps unnecessary costs which may be incurred because of poor or limited geological data can be drawn from isolated case histories. As an example, there were only two bore holes made prior to the excavation of the massive underground defense complex in Cheyenne Mountain for the

North American Air Defense Command (NORAD). Further geological exploration was scheduled but never funded because of a controversy about the project itself. When funding for continuation of the project was eventually released it was allocated for excavation alone, not geological exploration, and partly as a result, poor geology was encountered unexpectedly at a critical intersection of two project chambers. Eventually new plans had to be drawn up, rotating the original design in an attempt to avoid bad ground. Even then extensive and costly reinforcement was necessary at the worst intersection.[3]

Traditionally, geological surveying, measurements, and prediction are accomplished before any detailed designs and cost estimates are attempted. Although geophysical measurements are sometimes made during the course of the excavation process, the current practice is to rely heavily on the geological work prior to excavation. As improved techniques for in situ measurement of geological conditions are developed it is likely that greater emphasis will be placed on evaluating the information provided by these techniques to improve the safety and performance of excavating.

Depending upon the extent of the geological survey and measurement program, the information and data that it evokes might be used in site selection and feasibility determination, preliminary design and cost estimates, or detailed construction planning. However, as a result of both the coarse nature of geological measurements and the cost of detailed exploration programs, such decisions and studies are almost always based on incomplete information. Consequently, engineering judgment tempered by previous experience plays a significant role in the decision processes. We shall have more to say about this in the following pages, but given that the site, geometry, and orientation of a tunnel project have been chosen, we can focus attention on the fundamental data requirements imposed upon the engineering geologist.

The results of a geological exploration program should consist of sufficient amounts of data concerning lithological, hydrological, and rock-mass properties to enable a designer and contractor to plan a construction project with confidence. This includes both the quantitative aspects of engineering and excavation system design, and scheduling plans and cost estimates. In other words, the contractor wants answers to the following key questions:

1. What would be the most suitable excavation method?
2. What are the ground support and tunnel liner requirements along the length of a proposed tunnel?
3. How much ground-water inflow can be expected along the tunnel length?
4. What is the location of potential geologic hazards?

The extent to which such questions can be answered with precision and reliability determines to a large extent the ultimate cost-performance success of the construction project.

II. SURVEY AND PREDICTION TECHNIQUES

We shall present next a brief survey of those measurement techniques and procedures that are now in general use for geological surveying and prediction. Since comprehensive discussions along these lines are readily available in the literature,[4-9] we shall focus our attention primarily on the extent to which these various techniques are able to delineate geological discontinuities and inhomogeneities such as faults, joints, bedding planes, rock-soil interfaces, and ground-water concentrations. In addition, we shall present relevant cost data, and discuss the technical and economic factors which influence the scope of a typical geological exploration program.

A comprehensive geological exploration program typically involves the following kinds of activities:

- Review of available data (literature research)
- Surface exploration and mapping
- Subsurface studies
- Laboratory analysis of field samples

The degree to which efforts are directed in each area depends not only on technical and engineering considerations but also on economic factors and judgment. This will be elaborated below.

A. LITERATURE REVIEW

An exploration program generally begins with a survey of available literature dealing with geological and engineering geological information pertaining to the area of interest. The objective is not only to save time and expense but also to utilize the information to plan the remaining elements of the exploration program more efficiently and effectively. Of particular interest is information relating to the spatial distributions of rock formations along the tunnel route, the physical properties and quality of the rock types that might be encountered at depth, and expected or possible ground-water conditions during excavation. If underground construction data for previous projects in the general area are available, they would most likely be used to assess the structural characteristics of the geological strata, and possible problem areas. The sum total of such sources of information would be expected to aid the geologist in interpreting conditions with respect to possible problem areas, tunnel support requirements, and ground-water conditions. Of course, the amount of useful data that can be gathered depends on the extent of previous surface and underground construction in the general vicinity of the proposed tunnel.

B. SURFACE EXPLORATION

Surface investigations comprise the second step in the sequence of progressively refined studies and measurements. With the exception of built-up urban areas, most geographical settings are suitable for surface geological exploration. The objective of this phase of the program is to survey and map in detail the exposed rock formations in a wide area covering the contemplated excavation. The usefulness of this procedure depends on the degree to which geological formations and structures of interest are exposed at the surface. In some cases, aerial and surface reconnaissance is aided where necessary by bulldozer stripping of surface soil to expose underlying rock formations. This is usually an inexpensive way[4] to implement the surface work.

The results of this phase of geological exploration are recorded on a topographical map of the type made available by the U.S. Geological Survey. The map scale may vary between 1200:1 and 4800:1 and the following geological features are usually displayed:

- General geology (location and classification of generic rock types)
- Strike and dip of surface outcrops
- Location of fault zones and veins
- Description of foliation and joints
- Fracture densities as a function of location
- Degree of weathering

When the information is displayed in this form, it is useful to the geologist in connection with two main tasks: it serves as the basis for making a preliminary extrapolation of rock conditions to tunnel depth, and it aids in the planning of subsequent geological and geophysical measurements, such as core drillings and seismic surveys. It is worthwhile to emphasize that at this point the geologist cannot predict with a high degree of certainty what geological factors will be encountered at depth. The information, when evaluated and interpreted by an experienced geologist (and we must emphasize interpret) serves as a basis for perhaps semiquantitative estimates of expected conditions. Conditions are rarely predicted easily since much of the earth's outer crust consists of highly variable geological structures and conditions. Therefore, to increase the information usable for design purposes, additional measurements and tests are often planned, as a result of questions raised by the results of the surface geological mapping. Occasionally, field samples are collected during the surface survey for laboratory analyses and identification.

C. SUBSURFACE INVESTIGATIONS

As discussed in the previous sections, the geologist's chief goal is to measure and/or predict the geological conditions at the depth of interest. It is usually necessary to refine the data obtained from surface mapping by detailed investigations of areas of known faults, areas of potential geological problems, and ground-water conditions. Toward this end, a number of procedures and measurements are currently in use:

- Core drilling
- Pilot bore
- Field geophysical measurements

1. Core Drilling

Information concerning subsurface conditions is obtainable by drilling small vertical (or nearly vertical) holes down to tunnel depth, with the concommitant examination and testing of the removed material (core samples). Holes drilled in rock are usually about 3 in. in diameter, and the amount of core recovered is a function of the quality of the rock and the skill of the drillers. Data on rock properties and geological conditions as a function of depth are obtained through core logging, water testing, and laboratory measurements of core samples.

2. Core Logging

This is essentially the systematic recording of observations of rock properties for successive core samples. In particular, parameters such as rock type, fracture and joint spacing and orientation, density, and hardness are of immediate interest. Since heavy ground-water conditions are particularly influential in a tunneling operation, data on changes in the water level encountered, as well as porosity and permeability measurements and pumping tests, are of value.

3. Pilot Bore

In view of the inherent deficiencies in the techniques discussed above, the need for exploratory drilling ahead of a working face has been widely recognized. Current geological investigation techniques do not provide enough information for design purposes, nor are they capable of being applied simultaneously with the excavation process. As a result, it would be desirable to obtain in situ geological information in advance of a working face. Either a pilot bore prior to main tunnel excavation or a pilot bore sufficiently ahead of the main tunnel advance may supply the needed information.

The Straight Creek Tunnel Pilot Bore is an example of excavating a complete pilot tunnel in the immediate vicinity of the intended tunnel. A small pilot tunnel was excavated and subsequently surveyed by geophysical techniques. The resulting data indicated potential trouble spots, and some correlation of rock properties with construction parameters was made. If such a procedure could be made more economical, it would represent a very effective geological measurement tool.

The Japanese Seikan Tunnel across the Tsugaru Strait is an example of excavating a pilot tunnel simultaneously with the main tunnel, far enough ahead to guide the main tunnel operations. This project, in addition to the pilot tunnel, relies on information provided by the drilling of a small probe hole up to 1000 ft ahead of the excavation to locate potentially bad ground conditions.

4. Field Geophysical Measurements

In addition to the techniques mentioned above, surface measurements are occasionally made using seismic velocities as indicators of intrinsic rock properties and changing geological conditions. However, its effectiveness is frequently limited by insensitivities of the techniques used and by an inability to distinguish clearly between certain kinds of rock. Surface measurements of DC electrical resistivity have also been used to detect changing rock and ground-water conditions, but with modest success. However, data from the Straight Creek Tunnel Pilot Bore [8,9] indicate that such measurements may be of definite value in conjunction with other in situ techniques.

Some use has been made of borehole photography to provide direct observation of geological conditions inside the borehole.

Geophysical measurements of seismic velocities in boreholes are also made. Depending on the physical differences among the rock types encountered, such data can be used to correlate other surface geophysical measurements. Unfortunately, unless the boreholes are spaced close enough along a proposed tunnel route to reveal all geological changes bearing on engineering design and construction, the resulting information is only generally indicative of conditions to be expected. Core logs are often incapable of indicating the extent of geological discontinuities. As a result, the data yield only an incomplete picture of geological and hydrological conditions at tunnel depth. However, in mining operations core-boring techniques may provide all the useful information that is needed.[10]

D. LABORATORY TESTS

In addition to the logging and measurement techniques used in conjunction with core boring, the intact core samples are usually tested in the laboratory. The object of such tests is to determine those rock properties which influence the excavation method, support and liner design, and probable ground-water conditions. In particular, such parameters as unconfined compressive strength, hardness, fracture and joint spacing, and degree of weathering are of immediate interest. Prospective bidders and/or tunnel machine designers might perform additional tests of their own choosing to enable them to evaluate the relative advantage of drill and blast versus machine tunneling, but such tests are performed after the initial geologic investigation is made. In recent years, the rock quality designation (RQD)[7,11,12] has come into use as a simply measured indicator of overall rock quality. It is defined as the fraction of the recovered core pieces with a length greater than or equal to 4 in. Thus, it is an approximate measure of the influence of discontinuities on the rock mass encountered. This will be discussed in more detail in a subsequent section, but it suffices to say at this point that the RQD can be correlated at least partially with engineering and construction aspects of tunneling. At the present time, laboratory measurements of intrinsic rock properties are useful only in furnishing guidelines for support design purposes. The measurements are useful, but enough uncertainty remains to require the inclusion of large safety factors in design and construction.

E. COST CONSIDERATIONS

In general, one cannot readily provide rules which determine the optimum allocation of resources to geological exploration. The amount can vary significantly from one project to another and one geology to another. However, Table I-1 summarizes typical costs associated with current geological surveying and measurement procedures. They can be used to estimate the total cost of postulated exploration programs.

It should be mentioned that the cost per foot of core drilling depends somewhat on the diameter and ultimate depth of the hole. Thus it can be seen that drill holes of 500-foot depth might typically cost $5,000 or more each. This explains why their locations are chosen with care. Finally, it should be mentioned that in situ engineering tests for design purposes are usually more costly and time consuming than laboratory tests. This includes, in particular, radial jacking tests to measure the deformation of tunnel wall rock under various loading conditions.

TABLE I-1

COST ELEMENT OF GEOLOGICAL SURVEYING

1.	Core drilling into bedrock (3-in. diameter) with boxing of cores	$5-$25/ft
2.	Water pressure tests	$75/test
3.	Mobilization/demobilization (per drill rig and crew)	Variable (several hundred to several thousand dollars)
4.	Observation well (1 1/2 in. diameter)	$4/ft
5.	Surface mapping	$100/(day-geologist)
6.	Literature research	$2100/man-mo. (office)
7.	Laboratory tests	$25-$100/sample
8.	Seismic tests (surface)	< $1/lin. ft

REFERENCES AND NOTES

1. Dr. C. S. Robinson, C. S. Robinson & Associates, Inc., personal communication.

2. Mr. L. Herlin, Metropolitan Area Transit Authority, personal communication.

3. Mr. K. Fox, Corps of Engineers, personal communication.

4. S. D. Woodruff, Methods of Working Coal and Metal Mines, Vol. I, Pergamon Press, Oxford, 1966.

5. Subsurface Investigations, Vol. 1-4, Washington Metropolitan Area Rapid Transit Authorized Basic System (Clearinghouse PBL185757), 1967.

6. K. Szechy, The Art of Tunneling, (Hungarian Academy of Sciences, 1966), Chapter 2.

7. D. V. Deere et al., Design of Tunnel Liners and Support Systems, (Clearinghouse for Federal Science and Technical Information, PB183799), 1969.

8. C. S. Robinson and F. T. Lee, Results of Geologic Research at the Straight Creek Tunnel Pilot Bore, Highway Research Record No. 185, 1967.

9. J. H. Scott and R. D. Carroll, Surface and Underground Geophysical Studies at Straight Creek Tunnel Site, Highway Research Record No. 185, 1967.

10. W. Peters, Cost and Value of Drill Hole Information, Mining Congress 53 (1), p. 56, 1967.

11. D. Deere et al., Engineering Classification of In-Situ Rock, AFWL-TR-67-144, January 1969.

12. R. Peck et al., Some Design Considerations in the Selection of Underground Support Systems, (Clearinghouse PB190443), 1969.

APPENDIX II

GEOLOGY MODEL

by

F. H. Murphy

SUMMARY

This appendix describes the concept, code structure and user operation of the geology model which is a tool for building a file of data which represents the geological conditions found within a given three-dimensional model of a region of rock.

CONTENTS

I. OVERVIEW

The geology model is a part of the excavation simulation model. One of the requirements established for the simulation model by the Bureau of Mines was that it provide a realistic modeling of the geological conditions encountered during the process of tunneling; specifically, it was established that the rock which was encountered was not to be modeled as a homogeneous medium. It was also established that the excavation model was intended to be used as a research tool which would aid in evaluating the relative cost and performance characteristics of various techniques which might be used for tunneling through hard rock in the near future. This latter consideration led to a decision to design the overall model in such a way that the portion which was concerned with modeling geological conditions was a separate entity.

The geology model is intended to be a convenient tool for building a file of data which represents the geological conditions found within a given three-dimensional region of rock. The representation of the geology is meant to be exemplary. By this it is meant that the geology model is primarily intended for use in building files which represent hypothetical geologies which might be of interest in research. Even so, enough flexibility is provided so that reasonable representation of existing geological regions could be rather easily constructed, if desired. The sizes of the geological regions which are simulated, as well as the spacings of data points within the regions, are under the control of the user.

This appendix is intended to document the inputs, the methods of operation, and the outputs of the geology model. In doing this, it is convenient to discuss first the structure of the geology file which is generated; this gives some insight as to why the model is as it is. The structure of the model is then discussed in some detail. A discussion of the specific formats and uses of the various control cards follows. Finally, a detailed description of the subroutine named BENDER, which is used to simulate the tectonic warping of layers of rock, is given.

II. OUTPUT FILE STRUCTURE

The geology file produced by the geology model is a simple sequential (i.e., tape-like) file. This file consists of four parts, in order:

1. Dimensional Information
2. Rock Layer Information
3. Rock Property Information
4. Layer Position Information

Each of these four parts will be discussed in turn. It should be noted that there are no end-of-file marks between the parts of the geology file; the only end-of-file mark is located at the end of the file.

The dimensional information specifies the size of the region to be modeled and the horizontal spacing between data points. Implicitly, it also specifies the number of entries which will be found in the fourth part of the geology file--the layer position information. In order to see how this is done, imagine for a moment that you are well up in the air, looking down at a rectangular region of the earth's surface. This region is described, throughout the model, by means of the following directional notation conventions:

↑ Y, NORTH, J, OR N DIRECTION

→ X, EAST, I, OR M DIRECTION

The compass-like notation is used for input convenience. The X and Y notation is used when it is convenient to refer to points within the region by means of floating-point coordinates; either the I and J or the M and N notation is used when it is convenient to refer to selected points within the region by means of integer coordinates. Vertical levels are always referred to by floating-point numbers; the variable name Z is most commonly used for this purpose. The positive vertical direction is upward.

Within the model, this region is divided up into an integral number of grid squares. There are NX grid lines from right to left and NY grid lines from top to bottom. NX need not equal NY. These grid squares need not, in truth, be square. A scale factor can be associated with each of them. Thus, each square is SCALEX wide and SCALEY high. SCALEX need not equal SCALEY. The geology file contains geological layer position information for each point at which the grid lines cross.

Going back for a moment, then, the first part of the geology file contains four entries of dimensional information which specify the size of the region to be modeled and the horizontal spacing of the data points. In order, these four entries contain:

Position	Contents	Format
1	NX	I5
2	NY	I5
3	SCALEX	1PE18.10
4	SCALEY	1PE18.10

At the present time, the model can accommodate regions in which NX and NY are each less than or equal to 30. If these limits are exceeded, the array SURF in the geology model's main program should be redimensioned to SURF(NX_m, NY_m, 7) where NX_m and NY_m are the maximum desired values of NX and NY; no other changes are required. There values of SCALEX and SCALEY are not subject to any practical limitations.

The present version of the geology model allows the user to specify up to 25 different layers of rock, which may correspond to between 2 and 25 kinds of rock. If these limits are exceeded, the array INDEX should be redefined as INDEX($ILAYR_m$), where $ILAYR_m$ is the maximum number of layers desired. Depending upon the computer used, it may be necessary to change the PROGRAM card of the geology model to allow for the files

TAPE1, TAPE2, ..., through TAPE($ILAYR_m$). The array BUFF should also be redefined as BUFF($ILAYR_m$ + 2). Additional rock types are accommodated by redefining the array PROP as PROP(6, $IROCK_m$), where $IROCK_m$ is the maximum number of rock types desired.

The geology model allows the user to easily generate surfaces, which are interpreted as the upper boundaries of layers of specified kinds of rocks. The user is required to number these layers, for identification purposes, as he generates them. There is no requirement that the relative vertical positions of layers be in any way related to the identification numbers assigned to them.

The second part of the geology file is simply a copy of the values which the user placed in the array named INDEX. The value of INDEX(ILAYR) is the number of the rock type which the user specified as being found directly beneath the surface to which he gave the identification number ILAYR. Let us suppose that INDEX(ILAYR) = IROCK. Then, PROP (1 through 6, IROCK) contains the six parameters which the user specified as defining the kind of rock which he gave the rock identification number IROCK. The third part of the geology file is simply a copy of the values which the user placed in the array named PROP.

Explicitly, the second part of the geology file consists of rock layer information in the form:

Position	Contents	Format	
5	INDEX (1)	I2	Rock types for layers 1 through 25.
↓	↓	↓	
29	INDEX (25)	I2	

and the third part of the geology file consists of rock property information in the form:

Position	Contents	Format	
30	PROP (1,1)	1PE18.10	Parameters for rock type 1
31	PROP (2,1)	1PE18.10	
32	PROP (3,1)	1PE18.10	
33	PROP (4,1)	1PE18.10	
34	PROP (5,1)	1PE18.10	
35	PROP (6,1)	1PE18.10	
36	PROP (1,2)	1PE18.10	
↓	↓	↓	
179	PROP (6,25)	1PE18.10	

The fourth part of the geology file consists of NX times NY entries, in sequence, each entry being of the following form:

Entry Position	Contents	Format
1	I	1PE18.10
2	J	1PE18.10
3	Z_1	1PE18.10
4	Z_2	1PE18.10
↓	↓	↓
$ILAYR_m + 2$	Z_{ILAYR_m}	1PE18.10

Each entry is for a single point at which the grid lines cross; the coordinates of that point are the integers (I,J). The Z_L for L = 1 to $ILAYR_m$ are the vertical positions of the layers which the user has given the identification numbers 1 through $ILAYR_m$ respectively; Z values for layers which he has not specified are set to the value $Z = -10^{51}$. In interpreting the entries at a given (I,J) location, it is understood that, in case of overlap, an arbitrary rule determines which layer numbers take precedence.

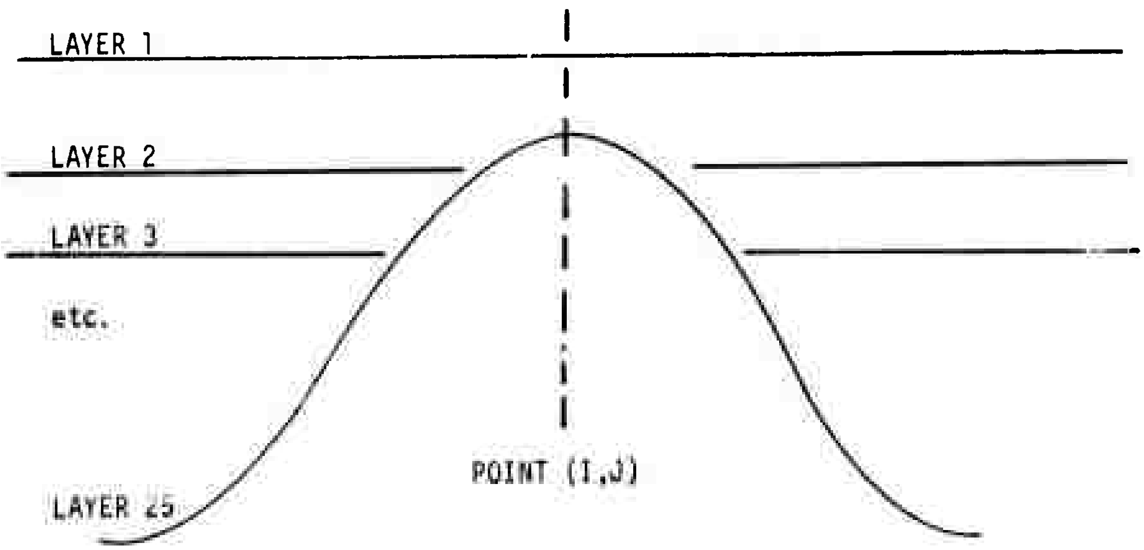
For example, suppose that at location (I,J) we were given the values Z_L for L = 1 through 25. We would receive them in the order given above:

L	Z
1	Z_1
2	Z_2
3	Z_3
↓	↓
25	Z_{25}

Our first step might be to sort the entries into increasing order by Z, and then use L as a precedence number:

L	Z
1	Z_1
25	Z_{25}
2	Z_2
3	Z_3
|	↓
24	Z_{24}

This might correspond to the condition:



The above illustration of how layer precedence relationships can be used is meant to be illustrative rather than definitive. No doubt the reader can imagine other geological conditions in which other precedence relationships would be useful; e.g., perhaps specific layer numbers might always be interpreted as representing the surface of the earth and the water table.

III. GEOLOGY MODEL STRUCTURE

There are two major phases of the geology model. During the first phase, the user is aided in manipulating surfaces on an NX by NY grid. These working surfaces may then be given layer number and rock type identification numbers, and be stored on auxiliary storage (usually disk storage) one surface at a time. The user is allowed to have up to seve working surfaces in existence at any one time. As was previously stated, the model as presently implemented will accommodate up to 25 layer surfaces.

The result of the first phase of operation is a collection of individual files, each corresponding to the Z values of a single layer surface; each such file of Z values is in the customary FORTRAN ordering by I and J. What is desired is of course a single file, ordered by I and J, which contains the Z values for every surface at each value of I and J. This phase, which begins upon the receipt of a MAKEFILE card, is essentially a reordering phase. During this phase, the values of NX, NY, SCALEX and SCALEY, as well as the contents of the arrays named INDEX and PROP, are written out onto the new geology file. The rest of the file is constructed by stepping through all values of I and J and, for each data point so defined, reading the corresponding Z value from each of the layer-surface files, consolidating these values into one entry, and writing this information onto the new geology file. When this process is completed, the operation of the geology model is terminated.

Figure II-1 illustrates the two-phase nature of the geology model.

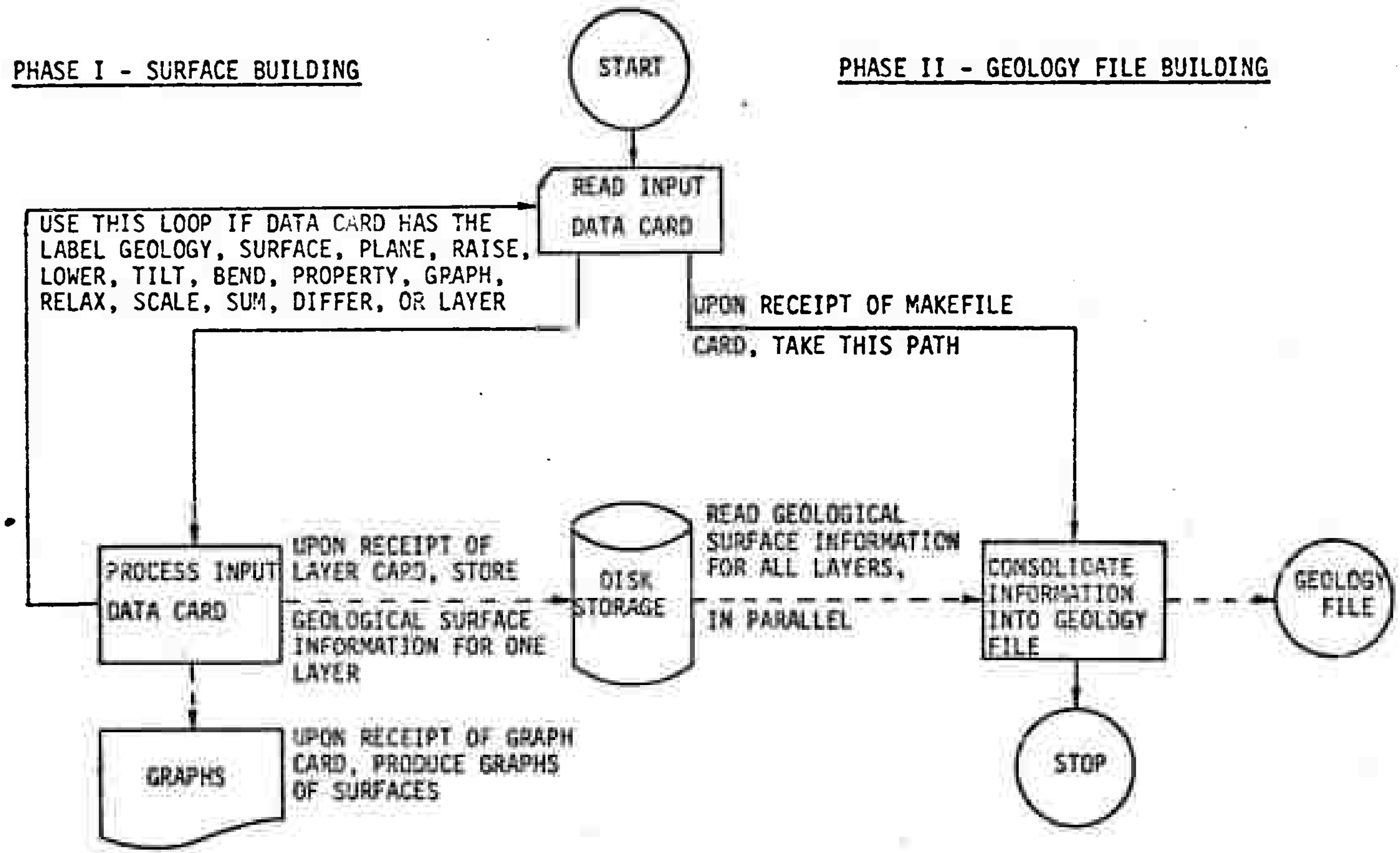


Figure II-1. The Two Phases of Operation of the Geology Model

IV. INPUT DATA CARDS

Sixteen different kinds of input data cards are used to control the operation of the geology model. Each kind is identified by a label which is punched into columns 1 to 10 of each card (left justified). The remaining space on each kind of card is divided up into seven equally sized data fields, each field being ten columns wide. All data entered into any of these data fields must be numerical and must include a decimal point. The formats of the sixteen kinds of input data cards are given in Table II-1. The purpose of each kind of cards and its associated data parameters is discussed in this section.

A. GEOLOGY CARD

The geology card must be the first card of the input data deck. There must be only one geology card per input data deck. Violation of either of these restrictions will cause a diagnostic message to be printed and the current run of the model to be terminated. The meanings of the variables NX, SCALEX, NY, and SCALEY are as given in Sec. II of this appendix.

B. SURFACE CARD

A SURFACE card provides a method of inputting a completely arbitrary surface. The main disadvantage to this is that many point-data cards (blanks in columns 1 through 10) may be required if NX times NY is large. In specifying an arbitrary surface, the SURFACE card must come first. SURFNO is the number by which the working surface which is to be created will be known; SURFNO can be any integer from 1 to 7, inclusive (but remember that decimal point!). The other data fields on the SURFACE card are ignored--unless they contain non-numeric data, which can cause a fatal error in the FORTRAN input-output routines.

The SURFACE card must be immediately followed by enough point-data cards to define the desired points on the surface. Two points can be defined per card; the problem which arises when it is necessary to define

TABLE II-1

INPUT CARD FORMATS

1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
GEOLOGY	NX	SCALEX	NY	SCALEY			
SURFACE	SURFNO						
	I	J	SURF(I,J)	I	J	SURF(I,J)	
PLANE	SURFNO	DEPTH					
RAISE	SURFNO	DISTANCE					
LOWER	SURFNO	DISTANCE					
SCALE	SURFNO(A)	SURFNO(B)	FACTOR				
SUM	SURFNO(A)	SURFNO(B)	SURFNO(C)				
DIFFER	SURFNO(A)	SURFNO(B)	SURFNO(C)				
TILT	SURFNO(A)	SURFNO(B)	DEGREE	AXIS	PTX	PTY	PTZ
RELAX	SURFNO	TOLER					
BEND	OLD SURF	NEW SURF	OLD MEDIAN	NEW MEDIAN	INFLUN		
GRAPH	SURFNO	SURFNO	SURFNO	SURFNO	SURFNO	SURFNO	SURFNO
LAYER	SURFNO	ROCKNO	LAYERNO				
PROPERTY	ROCKNO	PARAM1	PARAM2	PARAM3	PARAM4	PARAM5	PARAM6
MAKEFILE	MAXROCK	MAXLAYER					

an odd number of points is avoided by checking the value I times J before storing the value SURF(I,J). If I times J is zero (or blank) SURF(I,J) is ignored. The number of point-data cards is not checked. They need not be in any order, as long as all desired cards for the surface to be defined are together and immediately follow the appropriate SURFACE card.

C. PLANE CARD

As was noted above, the definition of large numbers of surface points can require large numbers of point-data cards and, therefore, large amounts of keypunching. This kind of effort is clearly unjustifiable when only very simple surfaces are required. Through the use of the PLANE card, one can establish a working surface with working surface identification number SURFNO, all of whose points are set to the value DEPTH, in one simple operation.

D. RAISE CARD

Geologies having layers whose layer surfaces are virtually identical, except for a vertical separation between layers, are not uncommon. The RAISE card was provided to ease the task of defining such a geological region. The use of the RAISE card simply adds the constant named DISTANCE to every data point of the working surface having the surface identification number SURFNO.

E. LOWER CARD

The same comments made in conjunction with the RAISE card are appropriate here. The use of the LOWER card simply subtracts the constant named DISTANCE from every data point of the working surface having the surface identification number SURFNO.

F. SCALE CARD

The use of the SCALE card is similar in nature to the uses of the RAISE and LOWER cards. In this case, each data point of the working surface named SURFNO(A) is multiplied by the scale factor named FACTOR, the result being stored in the corresponding location of the working surface named SURFNO(B). SURFNO(A) may equal SURFNO(B), if desired.

G. SUM CARD

The use of the SUM card causes the Z value for each I,J location of working surface number SURFNO(A) to be added to the Z value for the corresponding I,J location of working surface number SURFNO(B); the resulting value is placed in the corresponding I,J location of working surface number SURFNO(C). The Z values for the working surfaces numbered SURFNO(A) and SURFNO(B) remain unchanged unless one or the other or both of the working surfaces have the same number as working surface SURFNO(C). The numbers SURFNO(A), SURFNO(B) and SURFNO(C) may be equal to each other in any combination, if desired.

H. DIFFER CARD

The operation of the DIFFER card is identical to that of the SUM card, except that the corresponding I,J data points of working surface number SURFNO(B) are subtracted from those of working surface number SURFNO(A) in order to obtain the data point values for SURFNO(C). In short, surface A minus surface B equals surface C.

I. TILT CARD

Up until this point, all of the operations performed upon working surfaces have been vertical. It has also been considered desirable to provide some simple method of tilting surfaces, so that it would not be necessary to resort to the definition of surfaces through the use of SURFACE cards whenever the layer structure in a particular geological region happened not to be horizontal. The TILT card provides a simple method of tilting arbitrary surfaces.

The arbitrary surface which is to be tilted is that working surface having the surface identification number SURFNO(A). The data point values which result when this surface is tilted DEGREE degrees, in a right-handed fashion, around a horizontal vector through the point having the coordinates (PTX, PTY, PYZ) and pointing in a direction AXIS which is measured in degrees, in a compass-like fashion from north (or equivalently, the Y axis), are placed in the appropriate locations of the working surface having the surface identification number SURFNO(B).

This all sounds very complicated at first, but in practice, it is easy. The formulas used are well known.* The only difficult part of the operation stems from the fact that originally our working surface number SURFNO(A) has its Z values recorded at integer values of X and Y; after the tilting operation takes place, this is no longer true, in general. Yet this has to be true before we can store the Z values for working surface number SURFNO(B). It is therefore necessary to use a surface-fitting subroutine SRFIT in order to determine the second-degree equation which best fits that set of data points which is closest to each integer valued I,J pair for which we want a Z value for working surface number SURFNO(B). We then use the equation to interpolate in order to find the desired Z value. This must be done for every I,J pair where $1 \le I \le NX$, $1 \le J \le NY$.

Normally, the six closest data points should suffice for such a fit. It has been found desirable to use the closest eight in most cases. This results in a small amount of "smoothing" which is helpful at boundaries or at parts of the surface which have sharp bends. If it has trouble in fitting the surface with the eight closest points, the program will next try ten, then twelve points. If the trouble persists, diagnostic information is provided.

---

*See, for example, pp. A-255 of the Handbook of Chemistry and Physics.

There is no restriction as to how surfaces can be tilted. They can be tilted in a positive or negative direction, in small amounts or in barrel rolls. The only real constraint is that the resulting surface must be singly-defined at each integral value of I and J where $1 \leq I \leq NX$, $1 \leq J \leq NY$; otherwise, trouble will be encountered with SRFIT, as noted above.

J. RELAX CARD

We have discussed the use of completely arbitrary surfaces, specified through the use of the SURFACE card, and the use of planes specified through the use of the PLANE card. The RELAX card provides a means of achieving a middle ground between the relative advantages of realism and simplicity achieved through these two approaches.

Many geological surfaces may be adequately represented by "minimum energy" surfaces. That is, given the boundary points through which the surface would have to pass at the edges of the geological region which we are modeling, this type of surface is the smoothest which could be constructed which would still pass through the boundary points. An infinitely flexible membrane, such as a soap bubble, could be expected to provide the same kind of surface.

Mathematically, this kind of surface is called a harmonic surface; it satisfies LaPlace's equation in two dimensions:

$$\frac{\partial^2 F}{\partial x^2} + \frac{\partial^2 F}{\partial y^2} = 0$$

Given the boundary points for such a surface, there is a straightforward algorithm known as the relaxation algorithm which can be used in order to find the interior points which satisfy the above equation. This algorithm is iterative; its values converge to those of the desired surface. In general, this convergence is quite rapid at first, then more and more gradual as the computation continues.

The RELAX card allows us to use this algorithm. A typical approach would be to first use the SURFACE card method to specify only all of the boundary points for working surface number SURFNO. The RELAX card would then be used to find all of the interior points for this surface; these would have the property of representing the smoothest possible surface through the boundary points given.

The parameter TOLER allows the user to control the accuracy with which the surface is determined. The relaxation process will stop when, during one iteration of the algorithm, the value of no data point on the working surface <u>changes</u> by no more than TOLER. Note that TOLER measures the amount of change, not the amount of error as compared to the final, exact surface. Given reasonable surfaces, TOLER should probably be at least an order of magnitude smaller than the maximum error desired; when NX and NY are large, two orders of magnitude might be appropriate. If the user specifies that TOLER = 0 or leaves the specification of TOLER blank, the following automatic definition of TOLER takes place, in order to conserve computer time:

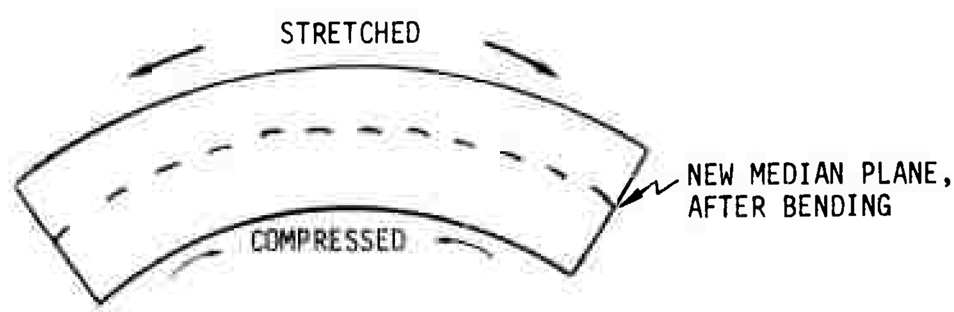
$$\text{TOLER} = \frac{\text{SCALEX} + \text{SCALEY}}{200}$$

Note that the RELAX card can be used in conjunction with any working surface whose boundary points are defined. The user is not restricted to using it in conjunction with the SURFACE card as outlined above.

K. BEND CARD

The subroutine (BENDER) used to implement the operation of the BEND card is the most complex subroutine of the geology model. It is discussed in detail in Sec. V, but an overview of its operation is provided here.

When something is bent, there is a median surface which is neither stretched nor compressed--only displaced. For example, consider a simple beam:



As we can see above, the stretched and compressed sides of the beam are not related to each other by a simple vertical distance relationship. While this is a two-dimensional example, the same kind of thing happens in three dimensions, except that there is a median surface which need not necessarily be a plane or cyliner.

The question which the bending subroutine attempts to answer is, "Given two working surfaces which represent the locations of the old and new median surfaces, prior to and after the bending of the rock, what is the new surface which resulted from the deformation of the old surface during this bending process?"

The exact analytical solution of this question would involve great data processing expense. We have provided an approximate solution, which seems to give reasonable answers, but even then involves significant expense when NX and NY are large, since the processing time is related to $(NX \text{ times } NY)^2$. Much of this expense is unnecessary since, when NX and NY are large, it is not usual for the displacement of the median surface at one I,J location on the grid to have much effect on surface deformations for I,J locations which are many grid points distant. The INFLUN parameter allows us to take advantage of that fact. Through its use, the consideration of the effect on deformation by causes more than INFLUN grid spacings distant can be eliminated. This makes the running time proportional to (NX times NY) times $(1 + 2 \text{ times INFLUN})^2$--a significant saving when NX and NY are large. If INFLUN is not specified, it is automatically set equal to three.

L. GRAPH CARD

From time to time, one may become curious as to the current Z values of a given working surface--especially after using a BEND card. The GRAPH card allows the user to print out X-Y plots of the surfaces, with X and Y coordinates labeled, and the appropriate Z values displayed. Plots that are too wide are automatically printed out in vertical strips which, when laid side by side, depict the entire surface. There is therefore no problem in producing plots, regardless of how large NX and NY become. Plots for several working surfaces can be produced with the same GRAPH card by placing their working surface identification numbers in sequential data fields on the card, beginning in the leftmost data field. The first blank data field encountered will terminate the process of producing plots. The process of producing plots does not alter any surface in any way.

M. LAYER CARD

The LAYER card is used in changing the status of a working surface to that of a geological surface. In doing this, the working surface is left unchanged; it is merely copied onto a disk file, and given a new number--a <u>layer</u> number as opposed to a working surface number. In addition, an entry is made in the array INDEX. This entry specifies the kind of rock properties which the user wants to have associated with this geological layer. In effect, in using the LAYER card, the user is saying, "Use working surface number SURFNO, associated with rock type ROCKNO, as geological layer LAYERNO."

N. PROPERTY

The PROPERTY card allows the user to specify the properties which are to be associated with rock type ROCKNO. The meanings of these parameters are not specified at the present time and are not relevant to this discussion.

O. MAKEFILE

The MAKEFILE card is the card which causes the consolidation of geological information into the geology file. In making the geology file, the geology model will assume that the user has specified properties for all types of rock having the numbers 1 through MAXROCK, inclusive. Likewise, it will assume that geological layer information is stored for all layers having layer numbers 1 through MAXLAYER, inclusive.

P. SUMMARY

Except for the first ten columns of any input data card, which must be alphabetic and left justified, all data entered on input data cards must be numeric and must contain decimal points.

The reader is cautioned to be thorough and consistent in redefining arrays within the geology model. For example, if the array SURF were redefined as SURF (27, 53, 7) in the main program GEOMOD, then the arrays named A, B, C, D, BX, and BY in the subroutine BENDER would have to be dimensioned as (27, 53), the array POINT in BENDER would have to be redefined as POINT(3, 1431), and the array GRID in the subroutine GRAPH would have to be redefined as GRID(27, 53). Failure to redefine these arrays outside of the main program GEOMOD would lead to incorrect indexing of these arrays and would cause erroneous results.

V. SUBROUTINE BENDER

The motivation in developing the BENDER program (Fig. II-2) was to create a subroutine which would geometrically alter geological layers in a reasonable and consistent way, and with a reasonable expenditure of computer time. The approach taken was geometrical rather than physical, on the basis of simplicity, available geological knowledge, and programming priorities.

When one begins to think about geometrical approaches to the warping of geological surfaces, some concepts seem to quickly come to mind and persist:

1. Any reasonable way of defining the three-dimensional deformation of a layered geological region seems to involve a description of what happened to the surface which, after deformation is the "median" surface in the sense that it was neither stretched nor compressed, but merely displaced.

2. It is true that, in a given pattern of deformation, there might be a large volume which might be neither stretched nor compressed and therefore, in the above sense, there can be no reasonable definition of any single "median" surface on the basis of its being neither stretched or compressed. While this is true, it is also true that, in this region, any surface would form an acceptable "median" surface, in the above sense.

3. In fact, when one begins to think about the time spans involved, the stresses and strains involved are probably not that well defined or understood; they may be dissipated by slippage, plastic flow, changes in the chemical makeup of the rock, etc. It is probably more realistic to think about deformations rather than stresses and strains, although the concept of a median surface is still an aid to understanding.

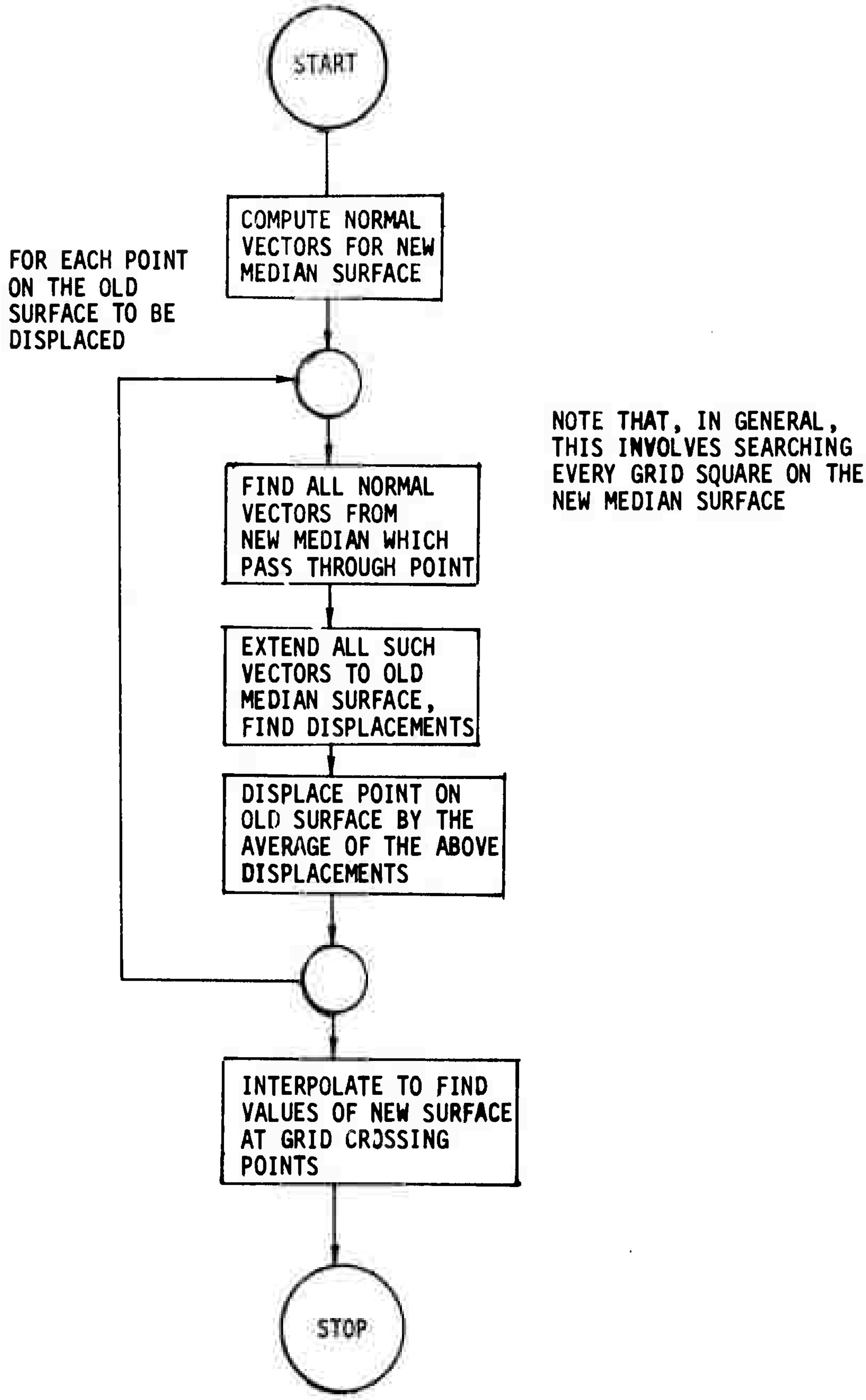
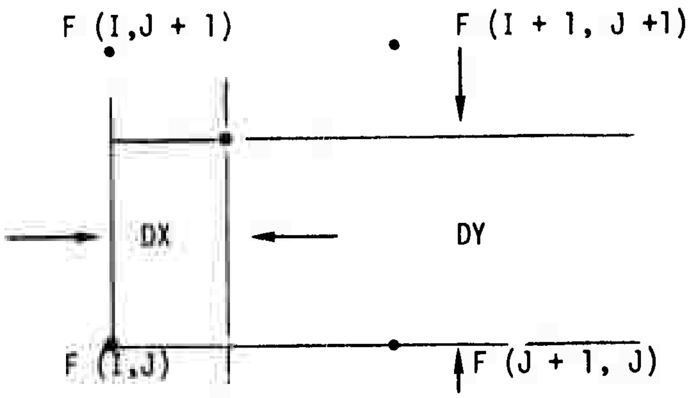


Figure II-2. Flow Chart of Logic of BENDER Subroutine

It is immediately obvious, after glancing at Fig. II-2, that the basic logic of the BENDER is exceedingly simple; it is also obvious, after looking at the 350 lines of FORTRAN in its listing, that its implementation may be straightforward, but it is not simple. For example, computing the normal vectors for the new median surface involves computing the partial derivatives in the X and Y directions at each grid line crossing point and storing them in the BX and BY arrays, respectively. These partial derivatives are then converted to the direction cosines of the desired normal vectors, the results of this computation again being placed in the BX and BY arrays. About 25 lines of FORTRAN code are involved.

Likewise, finding all of these normal vectors which pass through each grid line crossing point on the old surface is no simple task. First of all, this implies that the direction cosines for each grid line crossing point on the new median surface have to be examined in order to determine whether a normal vector from that point on the new median surface could go through each of the grid line crossing points on the old surface which is to be distorted. The mechanics of this operation infer that this processing step would have to be performed (NX times NY) times (NX times NY) times. This problem, whose solution was discussed in the preceding section, is compounded by the fact that the normal vectors from the new median surface will generally not originate at grid line crossing points, if they pass through grid line crossing points on the old surface which is to be distorted; some method of interpolation is therefore needed. The problem is further compounded by the fact that an iterative procedure is used to find the origination point of the normal vectors; there seems to be no better alternative to this procedure.

Although the iterative procedure could not be avoided, a quick, reasonable method of interpolation was found. If a function has a stated value at the four corners of a square grid, and if its value at some interior point is desired:



then if F(I + DX, J + DY) is computed as follows:

$$
\begin{aligned}
F(I + DX, J + DY) = & (1 - DX)\ (1 - DY)\ F(I,J) \\
& + DX\ (1 - DY)\ F(I + 1, J) \\
& + DY\ (1 - DX)\ F(I, J + 1) \\
& + DX\ (DY)\ F(I + 1, J + 1)
\end{aligned}
$$

The value of F(I + DX, J + DY) obtained is the same as if F(X,Y) were a harmonic function whose boundary values varied linearly along the boundaries between the four points in question. This interpolation scheme is used several times in the BENDER subroutine.

Having found a normal vector (suitably interpolated) from the new median surface which passes through a given grid crossing point on the old surface to be displaced, the next task is to extend the vector--in one direction or the other--until it intersects the old median surface, so that the displacement of the median surface can be calculated; this displacement will contribute to the displacement of point on the old surface to be displaced into the new, displaced surface. Again, it seems that the only way to do this is by an iterative procedure. The method used is similar to that used with the normal vectors, above. Basically, one makes a guess as to where the desired vector might originate or terminate, as the case may be. One then determines what correction is necessary to make the vector collinear (not necessarily in the same direction) with a previously determined vector. This procedure is repeated until either the computation drives the guesses out of bounds or the process converges to a solution, within a reasonable tolerance.

Finally one encounters the same problems with surface fitting that were discussed in conjunction with the TILT card (previous section). In fact, the same code is used, since the TILT routine is part of the BENDER subroutine. The same comments apply.

APPENDIX III

PROGRAMS TUNNEL AND GENTNL

by

P. K. Parish

SUMMARY

The two programs, TUNNEL and GENTNL, are alternative means of creating the geology file, TUNNEL, required by the excavation model. Program TUNNEL uses as input the GEOLOGY file generated by the geology model; program GENTNL allows direct creation of the TUNNEL file using only card input.

CONTENTS

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I. PROGRAM TUNNEL

A. PURPOSE

Program TUNNEL creates, from the GEOLOGY file written by the geology model, a TUNNEL file for input to the excavation model. The TUNNEL file describes the properties of the rock encountered in a specific tunnel through the three-dimensional area defined by the geology model. Execution and information flow is shown schematically in Fig. III-1.

B. GENERAL TECHNIQUE

The geology information is read from the GEOLOGY file and stored internally. The user, meanwhile, inputs (X,Y,Z) coordinates of the end points of any number of straight-line segments which describe the tunnel midline through the given geological area. The program advances along the midline of this tunnel at intervals of DELTA feet (see "OPTION" card), determining what geological layer contains each point. Whenever a new layer is entered (or the end of a segment is reached), a record is written for the TUNNEL file.

C. INPUT

1. The GEOLOGY file, generated by the geology model, containing three-dimensional layer and rock property information

2. User parameter cards

There are four types of input cards (see Table III-1): OPTION, START, NEWLEG, and END. Each card is considered to have up to 6 fields of 10 columns each. The first field contains the alphabetic keyword, beginning in column 1. Values entered in succeeding fields must contain decimal points, but may appear anywhere in the assigned 10 columns. A description of each card type follows.

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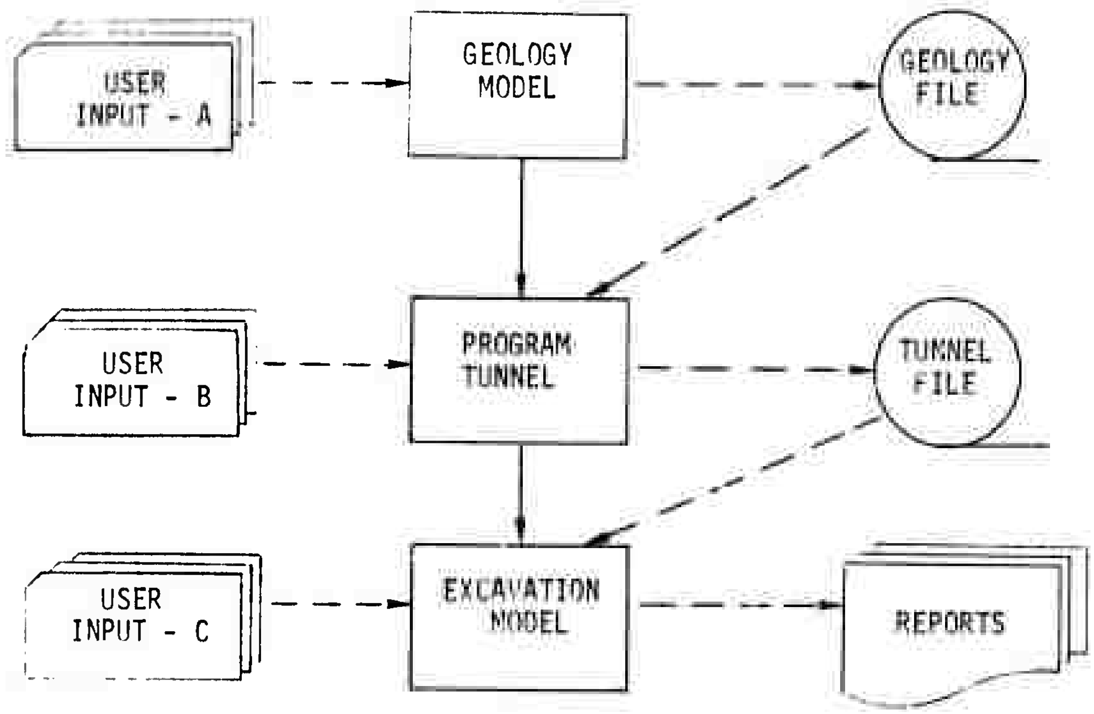

Figure III-1. TUNNEL File Creation by Program TUNNEL

TABLE III-1

INPUT CARD FORMATS FOR PROGRAM TUNNEL

1-10	11-20	21-30	31-40	41-50	51-60	
OPTION	DIAM	XORIG	YORIG	UNIT	DELTA	(Optional)
START	X	Y	Z			(Required)
NEWLEG	X	Y	Z			(Optional)
•						
•						
•						
NEWLEG	X	Y	Z			(Optional)
END	X	Y	Z			(Required)

OPTION Input Card

This card is used to override default values for certain program parameters. If default values are acceptable, this card is not required; if present, however, it must be entered first. For each parameter except XORIG and YORIG (for which zero may be the desired value), a blank or zero entry will cause the default to be in effect. None of these parameters is written to the TUNNEL file.

Field	Description	Default	Comments
DIAM	Tunnel diameter, in feet	10 ft	Currently not used by the TUNNEL program
XORIG	X location (feet) coincident with I=1 in geology model grid. This is the reference point used for X entries on succeeding cards.	1 ft	If OPTION card is present, this field must be filled in.
YORIG	Y location (feet) coincident with J=1 in geology model grid. This is the reference point used for Y entries on succeeding cards.	1 ft	If OPTION card is present, this field must be filled in.
UNIT	Number of feet represented by each SCALEX, SCALEY unit in geology model grid.	1 ft	
DELTA	The number of feet to be used by the program between test points along the tunnel midline.	20 ft	A smaller number here yields greater accuracy and longer processing time.

START Input Card

The X,Y,Z entries define the start of the tunnel midline through the area described in the geology model. The X and Y coordinates refer to the I,J axes of the geology model grid after application of XORIG, YORIG, UNIT, SCALEX, and SCALEY. The Z coordinate corresponds directly to those of the geology model, without transformation.

Hence, the X entered here will be transformed to the position X_I on the geology model grid by:

$$X_I = 1 + \frac{(X - XORIG)}{SCALEX \times UNIT}$$

and similarly for Y_J.

NEWLEG Input Card

If the tunnel is one straight-line segment, this card is not used. If the tunnel is composed of $N_s > 1$ segments, however, there will be $N_s - 1$ "NEWLEG" cards entered sequentially, each one containing the coordinates of the start of each new segment (except for the first segment, the coordinates of which are entered on the START card). There is no practical upper limit for N_s. X, Y, Z are interpreted as for the START card.

END Input Card

The last card entered must be an END card. It contains the position of the end of the tunnel midline. X, Y, Z are interpreted as for the START card.

D. OUTPUT

1. A printed report, showing the OPTIONs in effect, and a copy of the information written to the TUNNEL file.

2. The TUNNEL file, which will be input to the excavation model. Each logical record on the file contains the following fields:

   a. POSITION: The distance, in feet, from the beginning of the tunnel ($X = 0$) at which the following properties <u>cease</u> to apply. That is, the properties are applicable through the interval from the POSITION given on the preceding record (or from $X = 0$ for the first record) up to, but not including, this POSITION.

   b. PROPERTY 1: Unconfined compressive strength, psi

   c. PROPERTY 2: Abrasiveness

   d. PROPERTY 3: RQD, rock quality designation

   e. PROPERTY 4: In situ density, lb/ft^3

   f. PROPERTY 5: Ambient temperature, °F

   g. PROPERTY 6: Water inflow rate, gal/min

   h. IFLAG: Not used at present. May be utilized later to indicate mixed geology situations.

The FORMAT statement used to write each record is "FORMAT (7(1PE18.10), I2)." End-of-file is indicated by a dummy record containing a POSITION < 0.

For the logic of the TUNNEL program, as well as for the geology model, the entity assigned to any PROPERTY is completely arbitrary. The definitions shown here are those currently expected by the excavation model.

E. PROGRAM LOGIC

1. Main Program

Program TUNNEL reads the GEOLOGY file, processes the user input cards, and creates the TUNNEL file. The program technique is described in Sec. III-B, "General Technique." A flow chart is shown in Fig. III-2.

2. Subroutine GETLYR

This subroutine is used to determine which geological layer (LL) contains the point (XX,YY,ZZ).

Layer information is given in the GEOLOGY file only at the integral (I,J) grid points, hence interpolation may be required when seeking layer information at (XX,YY). Throughout the following discussion, $Z_{(I,J,L)}$ = vertical position in feet of the upper boundary of layer L at grid point (I,J).

First, (XX,YY) is translated to the geology model's (I,J) grid by:

$$XCOOR = 1 + \frac{(XX - XORIG)}{SCALEX \times UNIT}$$

$$YCOOR = 1 + \frac{(YY - YORIG)}{SCALEY \times UNIT}$$

The integers bounding (XCOOR, YCOOR), then, are given by:

$$ILOW \leq XCOOR < IHI$$

$$JLOW \leq YCOOR < JHI$$

The four grid points surrounding (XCOOR, YCOOR), therefore, are (ILOW, JLOW), (ILOW, JHI), (IHI, JLOW), and (IHI, JHI).

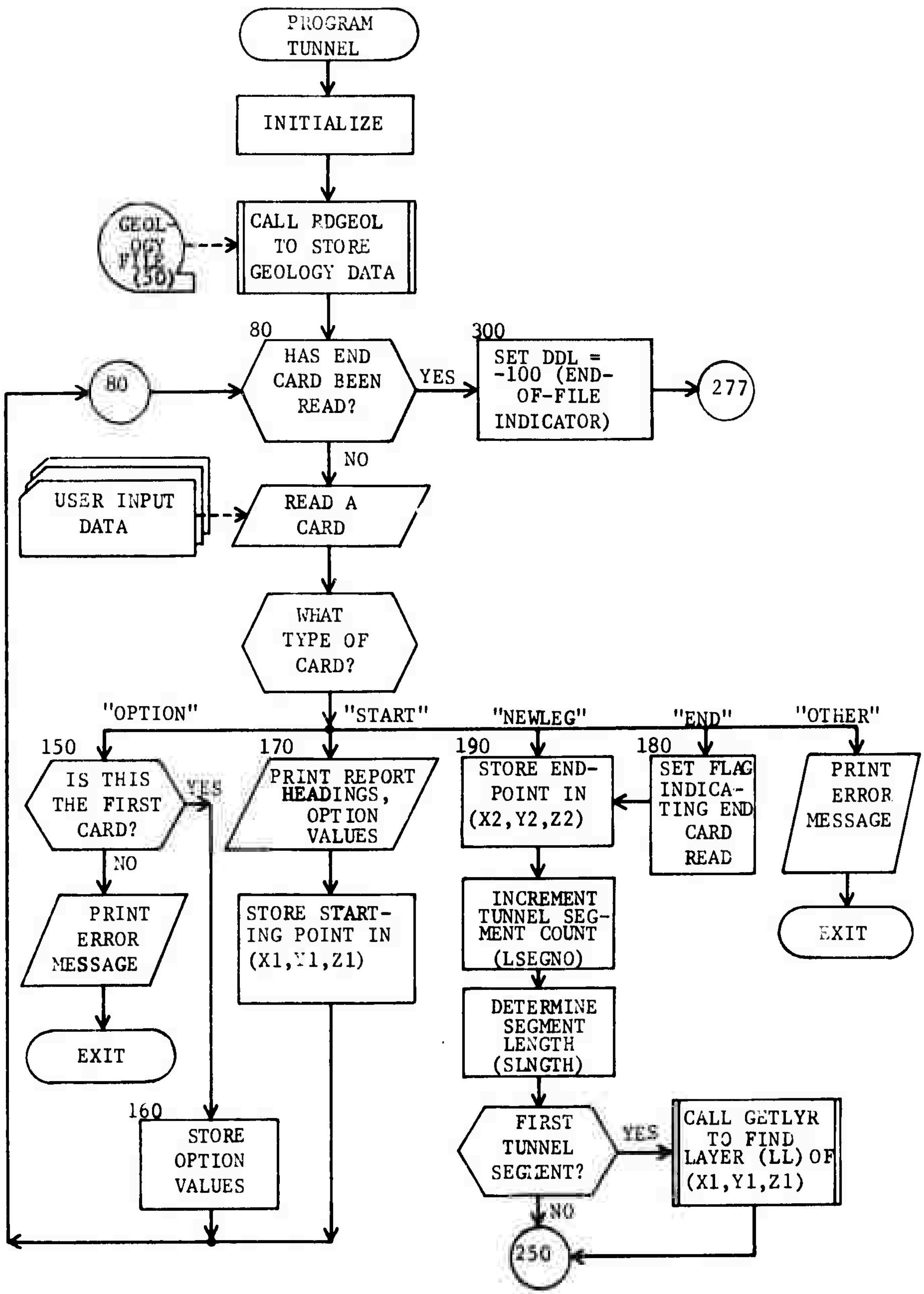

Figure III-2. Program TUNNEL Flow Chart

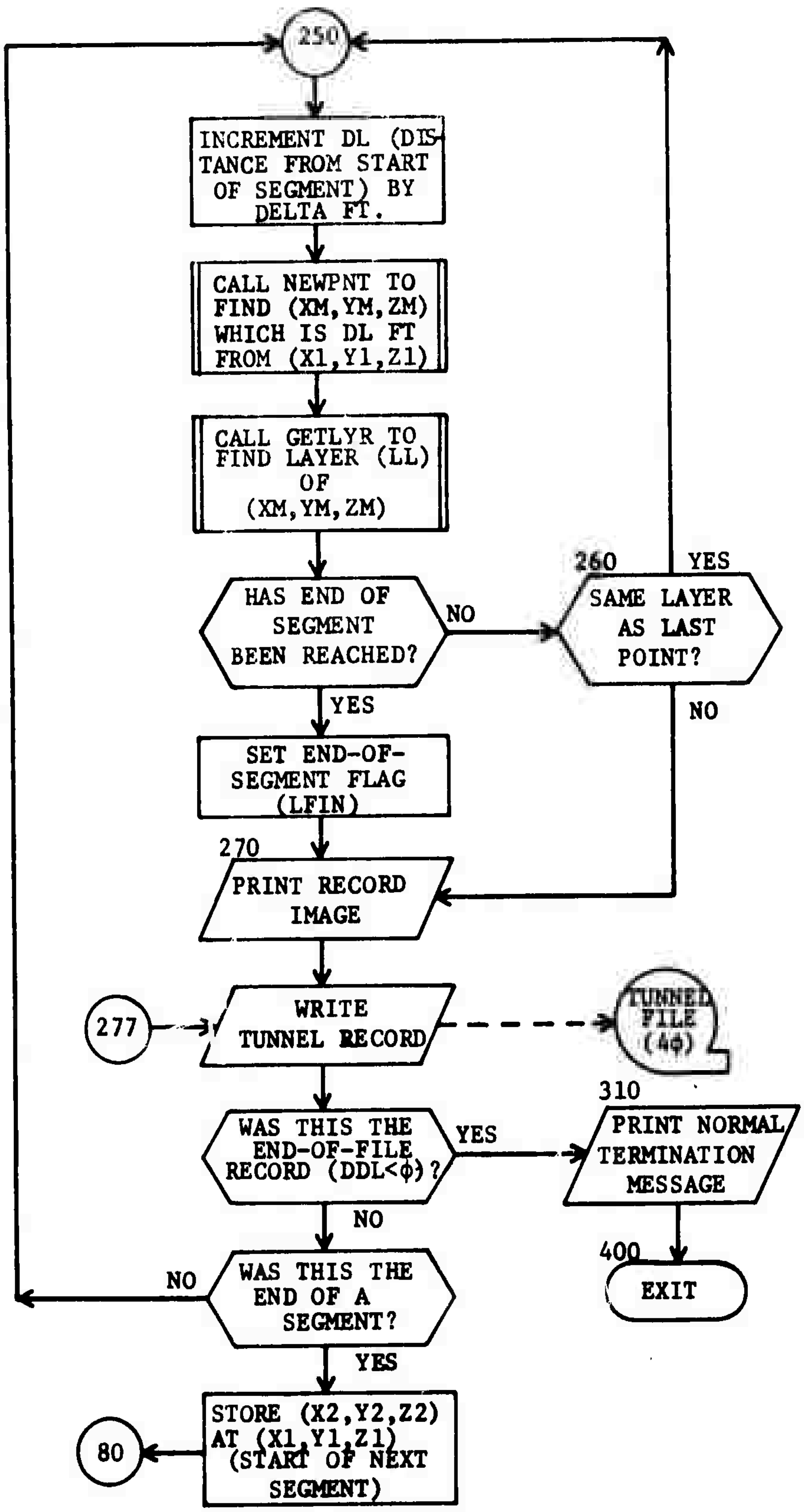

Figure III-2. Program TUNNEL Flow Chart (Cont.)

If (XCOOR, YCOOR) falls within the (I,J) grid (i.e., if $1 \leq ILOW \leq NX - 1$ and $1 \leq JLOW \leq NY - 1$), the processing is as follows

1. The layer information for the four surrounding grid points is examined. If ZZ is contained in the same layer at each point, that layer number is stored in LL, and the subroutine returns.

2. Otherwise, interpolation is required. To do this, the upper boundary of layer L in this grid square is assumed to coincide with the plane defined by the three points:

   - ILOW, JLOW, $Z_{(ILOW,\ JLOW,\ L)}$

   - IHI, JLOW, $Z_{(IHI,\ JLOW,\ L)}$

   - (XCOOR, JHI, ZC), where ZC is calculated by finding the equation of the line (2-point form) in the (X,Z) plane connecting the points $\left(ILOW,\ JHI,\ Z_{(ILOW,\ JHI,\ L)}\right)$ and $\left(IHI,\ JHI,\ Z_{(IHI,\ JHI,\ L)}\right)$, substituting XCOOR and solving for ZC.

3. The subroutine, then, cycles through for each layer L defined in the geology file, derives the equation of the plane (3-point form) defined by the above three points, substitutes XCOOR and YCOOR in this equation, and solves for Z. This value Z is stored in ZHOLD(L), and represents $Z_{(XCOOR,\ YCOOR,\ L)}$.

4. When ZHOLD(L) has been calculated for all L, the routine finds the lowest ZHOLD(L) such that $ZHOLD(L) \geq ZZ$. This L is stored in LL as the layer containing (XX,YY,ZZ).

Special cases exist if (XX,YY) falls outside the geology model grid. Here, each boundary grid line is assumed to define the area beyond it; e.g., the layer information for I= NX is taken to be true for all I > NX. Hence, if the given point (XX,YY,ZZ) is N,S,E, or W of the grid, only two (I,J) grid points need be examined, and interpolation, when necessary is done in two dimensions. For a point NE, NW, SE, or SW of grid, only one (I,J) gridpoint must be examined, and no interpolation is required.

3. Subroutine NEWPNT

Given the end points of a straight-line segment, (X1,Y1,Z1) and (X2,Y2,Z2), subroutine NEWPNT determines the coordinates (XM,YM,ZM) of the point on the line segment which is DL ft from (X1,Y1,Z1). It is used by program TUNNEL to retrieve each successive point along the tunnel midline, at intervals of DELTA feet, which is to be tested for layer information.

In the normal case, X1 ≠ X2, Y1 ≠ Y2, and Z1 ≠ Z2. The derivation of the calculations performed when this is the situation is as follows:

a. The formula which is to be solved for (XM,YM,ZM) is that for the distance, DL, between the points (X1,Y1,Z1) and (XM,YM,ZM):

$$DL = \sqrt{(XM - X1)^2 + (YM - Y1)^2 + (ZM - Z1)^2}$$

b. In order to reduce the problem in (a) to one unknown, YM and ZM are expressed as functions of XM using the 2-point form of the straight-line equation:

$$YM = Y1 + \frac{(Y2 - Y1)XM}{(X2 - X1)} - \frac{(Y2 - Y1)X1}{(X2 - X1)}$$

$$ZM = Z1 + \frac{(Z2 - Z1)XM}{(X2 - X1)} - \frac{(Z2 - Z1)X1}{(X2 - X1)}$$

c. Substituting the expression for YM and ZM from (b) into the equation in (a) yields:

$$DL^2 = [XM - X1]^2 \left[1 + \frac{(Y2 - Y1)^2}{(X2 - X1)^2} + \frac{(Z2 - Z1)^2}{(X2 - X1)^2}\right]$$

d. This is then solved for XM as follows: Let

$$A = 1 + \frac{(Y2 - Y1)^2}{(X2 - X1)^2} + \frac{(Z2 - Z1)^2}{(X2 - X1)^2}, \text{ a constant.}$$

a constant. Then

$$A(XM)^2 - 2A(X1)(XM) + A(X1)^2 - DL^2 = 0$$

from (c). Let

$$B = -2A(X1) \text{ and } C = A(X1)^2 - DL^2$$

both constants. Then we have

$$A(XM)^2 + B(XM) + C = 0.$$

XM can now be found by computing

$$\frac{-B \pm \sqrt{B - 4AC}}{2A}$$

(Note that $B^2 - 4AC$ simplifies to $4A(DL)^2$) and selecting the root which is between X1 and X2.

e. Once the required XM is found, the corresponding YM and ZM can be determined by substituting the value for XM in the expressions of (b).

Special cases exist if X1 = X2, Y1 = Y2, or Z1 = Z2. If only one of these conditions is true, then the same procedure is followed as in the normal case except that the problem is reduced to two dimensions. If two of the conditions exist, then the problem is one-dimensional, and the proper coordinate of (X1,Y1,Z1) is simply incremented (or decremented) by DL.

4. Subroutine RDGEOL

Entry RDGEOL reads the entire GEOLOGY file and stores the information internally for retrieval during program execution. The variables stored as they are on the file are NX, NY, SCALEX, SCALEY, INDEX(25), and PROP(6,25). Layer information is stored in ZSTOR(30,30,25), where ZSTOR(I,J,L) contains the depth in feet of layer L at grid point (I,J). A flag array, LFLAG(25), is set during reading such that LFLAG(L) = 1 if the GEOLOGY file contains data for layer L; it is zero otherwise.

Given II, JJ, and ZZ, where II and JJ are integers, entry FINDL examines ZSTOR(II,JJ,L) for all L to determine what geological layer (LL) contains ZZ. It is used by subroutine GETLYR.

II. PROGRAM GENTNL

A. PURPOSE

Program GENTNL, using card input only, creates a TUNNEL file for input to the excavation model, thereby bypassing the geology model. Execution and information flow is shown schematically in Fig. III-3.

B. GENERAL TECHNIQUE

The input cards are read, checked for ascending sequence by POSITION, and the values written to the TUNNEL file and to the printer. There are no practical restrictions to the number of cards or the number of PROPERTY combinations input.

C. INPUT

User data cards, containing the values which are to be written to the TUNNEL file, are the only input. The card format is shown in Table III-2. Any number of cards may be submitted, but the last card must contain a negative number in the first word (POSITION) to indicate the end-of-input. Each card is considered to have 8 fields of 10 columns each; each number entered must contain a decimal point, but may appear anywhere within its assigned 10 columns.

D. OUTPUT

1. A TUNNEL file for input to the excavation model. For a file description, see OUTPUT under program TUNNEL.

2. A printed copy of the contents of the TUNNEL file.

E. PROGRAM LOGIC

The program is basically a card-to-tape-and-printer utility which includes a sequence check on the POSITION field.

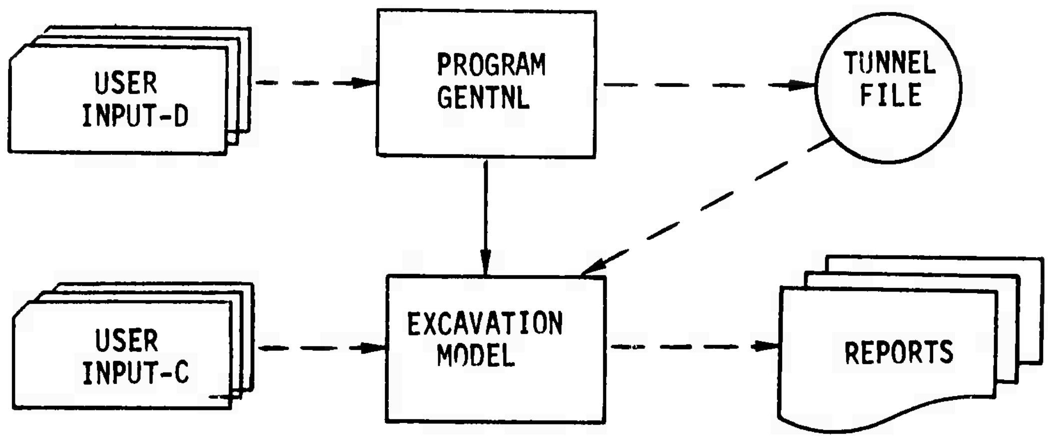

Figure III-3. TUNNEL File Creation by Program GENTNL

TABLE III-2

INPUT CARD FORMAT FOR PROGRAM GENTNL

1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
POSITION	PROPERTY 1	PROPERTY 2	PROPERTY 3	PROPERTY 4	PROPERTY 5	PROPERTY 6	IFLAG

Notes:

1. See description of TUNNEL file record for meaning of entries.
2. All numbers entered must contain decimal points.
3. Cards must be entered in ascending sequence by POSITION.
4. A card containing a negative POSITION must be placed at the end of the input deck; the remainder of this card may be blank.

APPENDIX IV

EXCAVATION MODEL

by

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SUMMARY

This appendix reviews the programming details of the excavation model and gives a short description of its conceptual basis. The subroutines simulating the tunneling activities are then described in detail, followed by a description of steps that need to be taken to incorporate the routines described into a control program which will coordinate the tunneling activities. Finally, the control logic required to coordinate any simulation is described, and the construction of a sample control program with its associated input and output routines is discussed.

CONTENTS

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FIGURES

SUBROUTINE FLOW CHARTS

SUBROUTINES (Cont.)

1. NOTES ON EXCAVATION MODEL DESIGN

The tunneling model is designed as a time-step simulation program. Each step in the simulation is considered to occur between one well-defined time and state of existence and another. The data required to so proceed is processed by subroutines that correspond to the various activities in the tunneling process being simulated. The subroutines simulate the whole excavation process. A control program must be provided by the user to coordinate the activities of the subroutines, initialize data, and print output reports.

The concept of the simulation proceeding from one well-defined time and state to another is implemented through the use of "old" and "new" working parameter common areas (OLDCOM, NEWCOM). During any given time step, the contents of OLDCOM describes the state of the tunneling system at the beginning of the time step; the NEWCOM contents describes the state of the tunneling system at the end of the current time step. Each subroutine receives its input information from OLDCOM and places its output information in NEWCOM. Each subroutine, therefore, determines the state of the system at the beginning of the new time step according to information received at the beginning of the current time step.

Figure IV-1 illustrates the flow of information which is processed by any given subroutine. Some of the information paths for some subroutines may be absent, but no subroutine has any information path not depicted in Fig. IV-1. It is emphasized that all information transfer to and from subroutines is through common areas; the control program is not in any way involved in information transfer to and from subroutines. From time to time, as the tunnel advances, the control program transfers new geology information to the common area of an old working parameter, but it never transfers information directly to or from a subroutine.

Parameter information for the use of the subroutines is read by the control program and is placed in the common areas. After cards are read

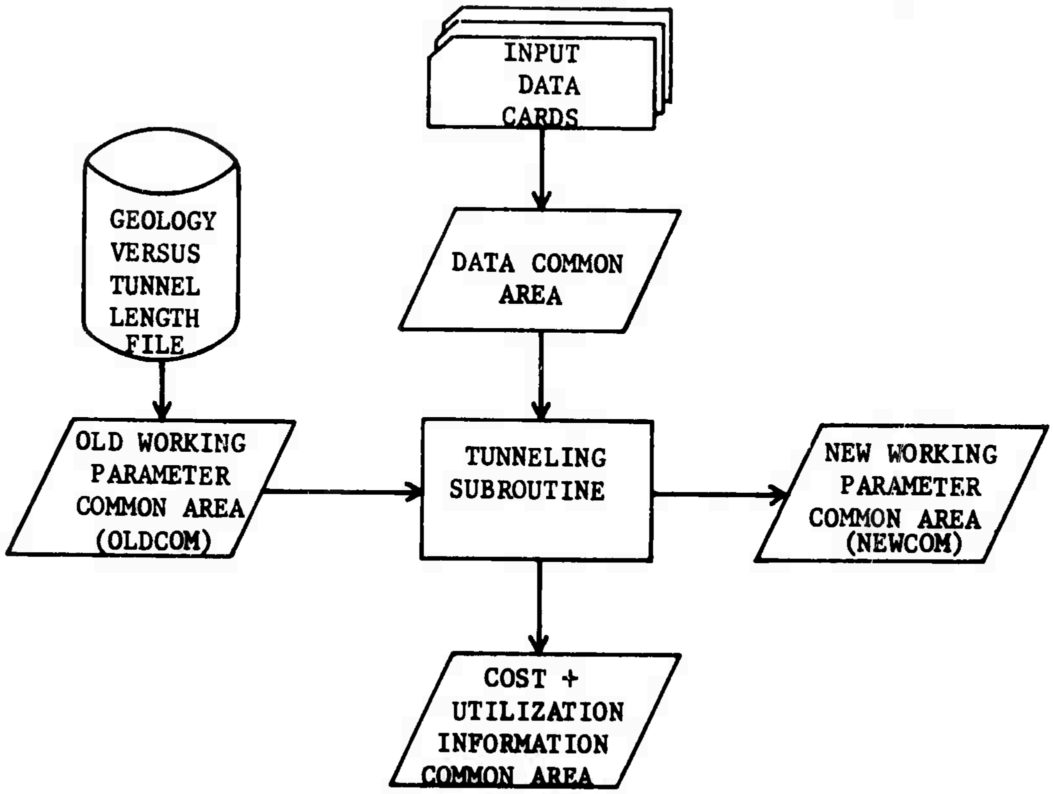


Figure IV-1. Information Flow for Individual Tunneling Model Subroutines in, each subroutine which has an initialization entry point is called at that entry. The subroutines contain default values for the various parameters. If no card input information has been provided for one or any of them, the model uses the default values. This approach was taken in order to avoid the need to specify large numbers of parameters. Parameter information for one execution of the model need contain specifications only for those subroutine parameters which are of interest.

The time stepping and the approach creating two working common areas leads to a simplification of reality, forcing the simulation model to operate in a discontinuous fashion (in reality, some tunneling processes are continuous). This is not considered to be a significant problem as long as the time steps are kept relatively short--perhaps about 1 to 10 minutes.

As the subroutines are executed, cost, availability, and utilization information is generated and cumulated. This information is placed in common areas by the subroutines involved. These common areas are used to compute values for printing reports.

II. DESCRIPTION AND FLOW CHARTS OF SUBROUTINES IN EXCAVATION MODEL

A. INTRODUCTION

The subroutine descriptions are grouped by the element of excavation and subgrouped by the type of tunneling they represent. For example, the first group of subroutines (Sec. IV-B) covers rock fragmentation, each type of fragmentation (boring machine, water jet, etc.) being described separately. Also discussed are the input and output routines written for the Layout Tunnel (see Vol. I of this report), which may be modified for use in other simulations. Figure IV-2 is a chart of subroutines related to the operations they simulate.

The text of this section of Appendix IV is organized as follows:

- A short description of the process being simulated.
- A list of the common blocks that need to be included in any control program written to simulate an excavation using a given process. Note that, in addition to the common blocks, any TYPE, EQUIVALENCE, and/or DATA statement involving a variable in the common blocks listed must be included in the model.
- A list of input variables, principally a NAMELIST (and its variables).
- A list of status variables through which the subroutines change the status of the process or of another process. Almost all of the status variables exist in two forms: present and future. They belong to the two common areas (of parameters) described in Sec. I of this appendix. The future form is that shown in the descriptions of routines. These variables are used to turn on and off the excavation in the sample control program. However, they can also be used to turn off other processes or change subroutine calls, thus giving the user more flexibility in simulating the tunneling process.

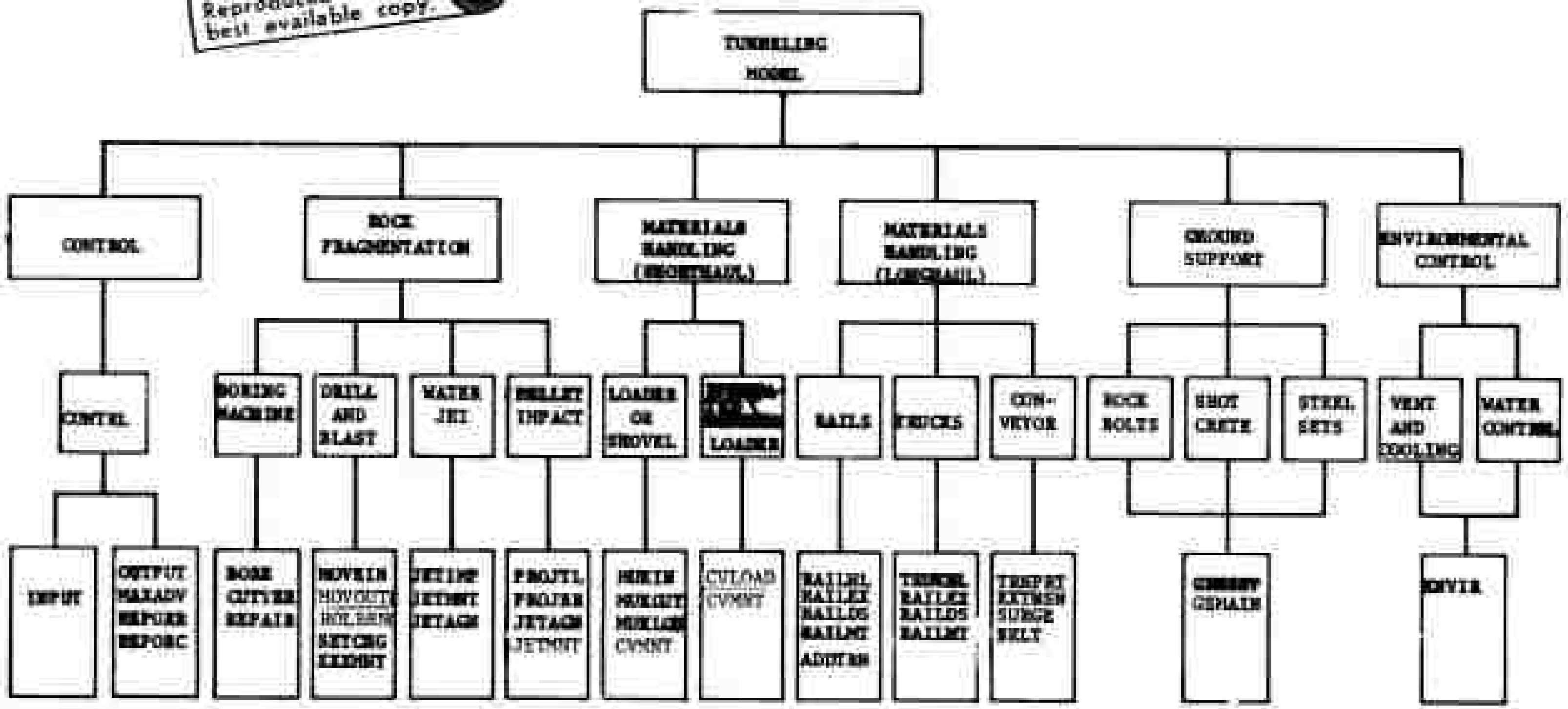


Figure IV-2. Subroutines of the Excavation Model

Input variables and status variables are defined in Appendix VI, and should be studied in conjunction with the listings and definitions in Appendix VI.

Several general statements that apply to the subroutines follow.

1. All subroutines have a normal entry point, used when the routine is called during the run for each time step. A few subroutines have two normal entry points (e.g., SURGE), and these are called by other subroutines, not by the control program.

2. Most subroutines also have an initialization entry point. Unless otherwise stated, the initialization entry should be called only once, at the start of the run immediately following the reading in of cards.

3. As mentioned above, status variables have two forms. The future form of the variable is usually the present form preceded by an F or L. For example, the status variable in CVMNT which indicates whether the loader is being maintained has a present form MCV and a future form LMCV. Each subroutine uses the present form to indicate the present status of the process described, and changes the future form as a result of computations. The subroutine never changes the present form. At the beginning of each time step the control program sets the present status variables equal to the future variables and thus updates the status of processes. For example, in the sample control program, LIEXCA is set equal to 1 in GRNSUP to indicate that ground support is falling too far behind the excavator and as a result the excavator must be turned off in the next cycle to allow ground support to catch up. At the start of the next cycle IEXCA (the present variable) is set equal to LIEXCA in the control program. When the checks are made to determine the status (MBORE) of the boring machine, IEXCA is found to be 1 and MBORE is set equal to 7, indicating that the boring machine is idle.

B. ELEMENT: ROCK FRAGMENTATION

1. Type: Boring Machine

The set of subroutines BORE, CUTTER, and REPAIR simulate rock fragmentation using a boring machine. These routines are currently set up so that their status variables are not in the two parameter common areas (OLDCOM, NEWCOM) but are single variables which have only a present form. This could be changed by having the user insert another form in the routines and put the two forms in COMMON/OLDCOM/, COMMON/NEWCOM/.

Common blocks: COMMON/ALL/
COMMON/BORE/
COMMON/PERFRM/
COMMON/MONEY/

Input variables: NAMELIST/BORE/
CL, CPC, DTA, DTC, DTCD, DTD, DTM, KK, PBM, R,
RC, RPM, TR, XCPC, EBOREQ, ETRANSL, DJMBMM, BOMEN, BOCST

Status variables: MBM
MBORE
LNCUTR

BORE - Rock Fragmenting

Operating time, plant and equipment costs, and labor costs for the boring machine for each time slice are computed and cumulated. If the boring machine is operating it computes the distance traveled by the boring machine and the job material cost of operating the machine.

CUTTER - Changing Cutters

Cutter wear is computed if the boring machine is operating and cutters are not being replaced. Cutter wear is checked and cutters are scheduled for replacement by setting LNCUTR = 1 if necessary. If cutters are in the process of being replaced, then one time step (DT) is added to the time already spent in replacement. If time spent in replacement is greater than or equal to the replacement time input by the user, then replacement of cutters is scheduled to end in the next cycle by setting LNCUTR = 0.

REPAIR - Repairing Boring Machine

The subroutine cumulates time until the user input time for scheduling maintenance is reached. At that point, maintenance is scheduled for the machine to start in the next time cycle by setting MBM = 1 and cost of the maintenance is computed. If maintenance is in progress, then time is added to the user input maintenance period. When the user input maintenance period has elapsed, maintenance is scheduled to end in the next cycle by setting MBM = 0.

2. Type: Water Jet

The set of subroutines JETIMP, JETMNT, and JETAGN simulate rock fragmentation using water jet impact, continuous and intermittent pulses.

Common blocks:	COMMON/ALL/
	COMMON/NJETS/
	COMMON/PERFRM/
	COMMON/MONEY/
	COMMON/OLDCOM/
	COMMON/NEWCOM/
Input parameters:	NAMELIST/JETS/PNOZZ, DNOZZ, NJETS, MODEJ, PPM, PULSED, ETAJ, ETAIMP, ENERGJ, DTCJET, DTMJET, DJMWJM, DTRJET, XRJET
Status variables:	LMWJ
	LMWJR
	LMWJM
	FHEATJ
	FQWATR

JETIMP - Jet Impact

In a normal entry a check is made to determine if the water jet is operating (MWJ = 0); if not the routine is exited. If it is operating, the subroutine computes the amount of rock disintegrated, the amount of heat and water added to the tunnel by the jet, and the cost for one time step.

JETMNT - Maintenance

A normal entry checks first to find whether maintenance is in progress. If not, then one time step is subtracted from the time left until the next maintenance period (time between maintenance periods input by user). If the remaining time is then 0, and if repositioning is not being done (MWJR $\neq$ 0), the jet is scheduled for maintenance in the next time step by setting LMWJM = 0 and set LMWJ = LMWJ + 1 to indicate jet not operating.

If maintenance is in progress at entry to the routine, the time elapsed for maintenance is increased by one time step. If the user impact time for maintenance (DTMJET) has been reached or exceeded, the jet is scheduled for removal from maintenance in the next time step by setting LMWJMC = 1 and subtracting 1 from LMWJ, and the cost is increased by the cost of a maintenance period.

JETAGN - Repositioning in Progress

The first check in a normal entry determines whether the jet is operating; if not, then if maintenance is in progress the routine is exited. If maintenance is not in progress, if the jet is not operating, and if repositioning is being done, one time step is added to the elapsed repositioning time and a check is made for repositioning completed. If it is completed, then its completion is scheduled for the next time step (LMWJR = 1 and LMWJ = LMWJ - 1).

If the water jet is operating at normal entry to the routine, then the distance traveled by the jet since the last repositioning is checked.

If it is greater than the user input maximum allowed distance, repositioning is scheduled for the next cycle (LMWJR = 0, LMWJ = LMWJ + 1).

3. Type: Projectile Fragmentation

The set of subroutines PROJTL, PRJBR, JETAGN, and JETMNT simulate rock fragmentation using projectile impact. The routine to simulate repositioning of the guns is the same as for the water jet, as is the maintenance routine. The initialization and normal entry points are different, however (PRJAGN and PRJPOS for the repositioning routine, PRJMNT and PRJRPR for the maintenance routine).

Common blocks: COMMON/ALL/
COMMON/NJETS/
COMMON/PERFRM/
COMMON/MONEY/
COMMON/OLDCOM/
COMMON/NEWCOM/

Input parameters: NAMELIST/PELLET/DTCJET, DTMJET, ETAGN, ETAIPT, WPRJ, VELPRJ, VOLPRJ, NGUNS, CSTPRJ, PRJPM, CPBRL, TRBRL, BLT, XRJET, DJMWJM, DTRJET

Status variables: LMPI
LNBARL
LMWJR
FHEATJ

PROJTL - Rock Fragmentation

In a normal entry a check is made to determine if projectile guns are operating. If yes, rock fragmented, advance of face, power costs, and heat generated are calculated for one time step. Total job materials cost for rock fragmentation is incremented. If no, the subroutine is exited.

PRJBR - Barrel Replacement

In a normal entry a check is made for barrel replacement in progress; if it is not, time elapsed since replacement is increased by one time step. Time elapsed against user input time between replacements is checked. If it is time for replacement, repositioning of barrel in progress is checked. (MWJR = 0). If it is not, barrel replacement is scheduled for next time step (LNBARL = 0, LMP1 = LMP1 + 1).

If on the first check in a normal entry barrel replacement is in progress, then time elapsed since barrel replacement began is incremented by one time step. A check is made for replacement completed. If completed, end of replacement is scheduled for next time step (LNBARL = 1, LMPI = LMPI - 1). Job material cost (DJMRD) is incremented by cost of replacement.

4. Type: Drill and Blast

This set of four subroutines simulates rock fragmentation by drilling and blasting. The four subroutines provided are: MOVEIN, MOVEOUT, HOLEBRN, SETCHG. A maintenance routine which can be patterned after the general maintenance routine XXXMNT shown in Appendix VI must be provided by the user. Note that variables chosen for maintenance times and costs must be added to NAMELIST below and to COMMON/BLAST/.

Common blocks: COMMON/ALL/
COMMON/MONEY/
COMMON/PERFRM/
COMMON/BLAST/
COMMON/OLDCOM/
COMMON/NEWCOM/

Input variables: NAMELIST/BLAST/PF, TYPEPF, TCHG, MEN, NH, CCAP WPL, CPL, CEX, CM, ND, LD, NHB, NDB, LDB, POD, ADH, SE, POB, LBIT, LSTEEL, LBURN, TIN, TOUT, CSTEEL, CBIT, CBURN, ADH, ADB

Status variables: LNDRLB
LNCHRG
LJUMOT
LJUMIN
LNDRIL

HOLBRN - Drilling

The subroutine simulates the drilling of holes of a burn pattern with drifter drills and burn-cut drills. In a normal entry one time step is subtracted from both time to drill holes with percussion drills and time to drill with burn-cut drills. If the result for percussion drills is positive, then the result for burn drills is checked; if both are positive, then drilling is not finished and the subroutine is exited. If one or both of the results are negative, drilling for one or both is scheduled to end in the next cycle (LNDRIL = 1 and/or LNDRLB = 1) and costs of drilling are calculated before the main program is resumed.

Note: Initialization must be redone for each drilling period. Therefore, the control program must reset to ICYCLE = 1 when drilling is to be done.

SETCHG - Setting Charges

The subroutine simulates setting the blast charge. In a normal entry, one time step is subtracted from the time remaining to set a charge. If time still remains, the main program is executed. If no time remains, the finish of setting charge for the next cycle is indicated (LNCHRG = 1). Job materials costs for setting charges are computed and a return main program is executed.

Note: This routine, like HOLBRN, must be initialized for each drilling period.

MOVOUT - Moving Out Drilling Equipment

This subroutine simulates moving out drilling equipment. In a normal entry the time to move out is decreased by one time step. A check is made to determine whether moving out is completed. If it is, then end of moving is scheduled for the next time cycle by setting LJUMOT = 1.

Note: This routine must be reinitialized each time moving is done by setting ICYCLE = 1.

MOVEIN - Moving Drills In

This subroutine simulates moving drills in. A normal entry first decreases moving time remaining by one time step. Then, if no time remains, the end of moving is scheduled by setting LJUMIN = 1. Also, the number of feet that the tunnel will be advanced (DX) and the volume of muck created (DV) for this drilling and blasting cycle is computed here.

Note: This routine must be reinitialized each time moving is done by setting ICYCLE = 1.

C. ELEMENT: MATERIALS HANDLING (SHORT HAUL)

1. Type: Integrated Conveyor Loader

This set of subroutines simulates moving muck from the face area. It must be used with another set of subroutines for long haul (e.g., rails). Together the two sets simulate removal of the muck to the discharge area. The integrated conveyor loader is simulated by two subroutines CVLOAD and CVMN1.

Common Blocks: COMMON/ALL/
COMMON/OLDCOM/
COMMON/NEWCOM/
COMMON/WHEELS/
COMMON/CONVEY/
COMMON/PERFRM/
COMMON/MONEY/

Input parameters: NAMELIST/LOADER/AB, VBI, SM, TCCV, TMCV, WMR, MLTYP, ECONEQ, ECONESS, JMCV, CVMEN, CVCST

Status variables: LMCV

LLOADR

LMFLAC

Note: Operating time for the total muck hauling (short haul and long haul) is computed in the long-haul subroutines. Long haul and short haul each compute down time.

CVLOAD - Loading Muck

One time step is added to labor time used for the loader, operating time for materials handling is updated, plant and equipment costs are updated for the time period advance. If the loader was unable to handle all the muck on the last cycle, or no train was available for loading the excess muck remaining is computed, then the total muck to be moved is computed. The muck is then either loaded onto vehicles (MLTYP = 1), or carried away by a conveyor (MLTYP = 2). (A check is made to determine if the long-haul system will take it all. If not LLOADR is set to 1 to indicate that it is overloaded.) If rails or trucks are the long-haul system and none is available for loading, LLOADR is set to 1. After loading the vehicle is sent to the discharge area if it is full.

CVMNT - Maintenance

One time step is added to the time elapsed since the last maintenance period. If the user input time between maintenance periods has been exceeded, maintenance is scheduled for the next time step by setting LMCV = 1.

If maintenance is in progress, then one time step is added to the time already accumulated for this maintenance period. If the time accumulated is greater than or equal to the user input maintenance period, the loader is scheduled to go back into operation in the next time step by setting LMCV = 0.

2. Type: Machine Loaders and Shovels

This set of subroutines simulates removing of muck from the face area and is interchangeable with the integrated conveyor loader set. It is to be used with one of the sets of subroutines for long haul. Together they form the simulation of materials handling in the model. It consists of three subroutines, MUKLOD, MUKIN, MUKOUT; and a fourth routine, CVMNT, is used for simulating maintenance. (The same routine, CVMNT, is used by the integrated conveyor loader.) Note that MUKIN and MUKOUT status variables must be set = 0 in the control program to initialize each move in and out, respectively, from the face.

Common blocks:	COMMON/ALL/
	COMMON/COMOLD/
	COMMON/COMNEW/
	COMMON/WHEELS/
	COMMON/CONVEY/
	COMMON/PERFRM/
	COMMON/MONEY/
Input variables	NAMELIST/SHOVL/
	STIME, QDMR, DTMO,
	DTMI, TMCV, TCCV,
	MLTYP, JMCV
Status variables:	LMKIN, LMUKOT,
	LLODR, FQL

MUKIN - Moving In Shovels

In a normal entry, the routine determines whether muckers are in the process of being moved to the face. If not, nothing is done. If they are being moved in then their moving time is decreased and a check is made to determine if the move has been completed. If it has, LMKIN is set to 1 to indicate completion.

MUKOUT - Moving Out Shovels

This routine handles the moving of muckers away from the face in exactly the same way MUKIN handles their moving to the face.

MUKLOD - Loading Muck

In a normal entry, the routine first determines whether a continuous main-line system (long-haul system is a conveyor belt) is being used. If it is, then the mucking rate is computed and compared with the muck to be moved. If the mucking rate is not adequate, LLODR = 0 is set to indicate mucking still in progress, load as much as possible. If the mucking rate is adequate, muck is loaded. If a unitized main-line system is being used instead of a continuous system, then a first check is made to determine if units (e.g., trains) are being switched. If yes, the time used for switching has one time step added to it. Time used for switching is compared with time needed to complete switching. If still more time is needed, no loading is done. If switching is finished and time is left, then the mucking rate is computed for time remaining. The number of units per vehicle is checked (e.g., muck cars per train). If there exists only one unit per vehicle, the full vehicle just switched with the empty one is released. If there is more than one unit per vehicle, a check determines if all units are filled; if so, the vehicle is released. Whether a vehicle is released or not, the computation for loading muck described below is done for whatever time remains.

If no vehicles are being switched, the calculation of the mucking rate is made. If it is adequate for the muck to be loaded, LLODR is set to 1 to indicate loading is complete. If unit is full after loading, switching time is set (TIMEL) and the check for switching time is made as described above. If the unit is not filled, the routine is exited.

D. ELEMENT: MATERIALS HANDLING (LONG HAUL)

1. Type: Rails

The set of subroutines simulates a long-haul rail system to carry the muck to the discharge area. This set in conjunction with a set of short-haul subroutines from the materials handling element of tunneling. The routines in the set are RAILHL, CUBIC, ADDTRN(I), RAILDS, RAILEX, and RAILMT.

Common blocks: COMMON/ALL/
COMMON/WHEELS/
COMMON/OLDCOM/
COMMON/NEWCOM/
COMMON/MONEY/
COMMON/PERFRM/

Note: The routine CUBIC does not need any common blocks.

Input variables: NAMELIST/RAILTS/ AE, AF, AMAX, AMAXL, AMINL, BSL, CARCAP, CP, DE, DF, DTAS, DTMA, DTU, NSWCIF, NGEO, NEXON, XDE, AB, VBI, SM, EL, FC, FR, FT, HPA, HPEV, HPEA, HPFA, HPFV, HPV, LOCO, MC, ML, NCARS, NPOINT, NTD, NTM, NTMAX, XP, NTMILP, NTMLPP, NTRACK, SL, TCURVX, TCURVY, TMAINT, TWE, VD, VE, VF, VS, VMAX, WC, WL, XDX, MAXLD, NVEHCL, NUMSWT, SWITCH, ISTA, TPOS, TSPD, TMAIN, KSTOP, MLTYP, WMR, ELOCO, EMUCKC, ETRACK, ESWITC, EUNLOA, ERMAIN, JMMHM, NUMLD, ISW, RAMEN, RACST.

General status variables: LLUHCL
LNBYBY
LNSWCH
LIFILD
LKUNLO
LLSTOP
LNTRADA
LNVHCL
LNMSWT
NUMLD

Status Variables for Each Train:

FTSTAT (J, I), J Jth Train/Truck

I = 1 Status (see below)
= 2 Position, feet from discharge area
= 3 Speed, mph
= 4 Days since last maintenance, days

FTSTAT (J, 1)

= 0 Train/truck is stopped, EMPTY reason given
= 1 Train/truck is stopped, FULL by JSTOP(J)
= 2 Train/truck is excelerating, E

= 3 Train/truck is excelerating, F

= 4 Train/truck is going at full speed, E

= 5 Train/truck is going at full speed, F

= 6 Train/truck is decelerating, E

= 7 Train/truck is decelerating, F

= 8 Train/truck is in switch, E

= 9 Train/truck is in switch, F

= 10 Train/truck is in discharge area

= 11 Train/truck is in maintenance area

ISTOP

= 0 Continue train/truck system

= 1 Shut down train/truck system

= 2 Bring up train/truck system

LKSTOP(J)

= 0 Not stopped

= 1 At face, loading

= 2 In switch, train stopped ahead

= 3 In switch, train approaching

= 4 External reasons

= 5 In switch, waiting to enter discharge area

= 6 In switch, waiting to enter load area

= 101, 102 ... At face, in queue

FUTIME(J) = Time to unload train J

FTOP (J) = Cumulative operating time of train J

FTFC(J) = Cumulative cost of train J

Status variables for each switch K: Kth switch

FSWTCH(K) = Distance in feet of centroid of switch K from discharge area.

RAILHL - Handling Muck by Train

The subroutine first adds DT to the labor time for rails. It also computes plant and equipment costs and down time for the rail system. Then it sets into local variables the (see Table IV-2 for status codes):

Status of each train	(ITSTAT(J, 1))
Position of each train	(TSTAT(J, 2))
Speed of each train	(TSTAT(J, 3))
Maintenance factor	(TSTAT(J, 4))
Reasons train stopped	(KSTOP(J))
Cumulative cost for train	(TFC(J))
Operating time of train	(TOP(J))

It then divides DT into smaller time cycles, and if the system is operating puts each train through the smaller time cycles until DT is reached, changing the train's status as indicated by its status at the beginning of the cycle and what is happening to other trains. For example, if train 1 is waiting to move toward the discharge area, and train 2 is moving back from unloading to loading area, train 2's progress will be calculated and monitored by train 1. When train 2 is back to the loading area then train 1 will be allowed to start for the discharge area.

If the system must be brought up or shut down, this is done first and then each train is put through the small time cycles. After all small time cycles are finished, the global status variables JSTAT (J, 1, etc.) are reset to the updated values of the local variables and the subroutine is exited.

CUBIC

This routine is a function which finds the first real root of a cubic equation.

RAILDS - Unloading Muck at Discharge Area

This subroutine accounts for unloading much from trains. If unloading has been stopped (KUNLO = 1), the routine does nothing; otherwise, it determines whether any train is unloading. If train J is unloading (ITSTAT(J, 1) = 10), the time remaining before it completes unloading is computed. If it will be finished before the end of the current time cycle, train J is added back into the system (if system is 2 track) or (if system is 1 track) subroutine ADDTRN is called and adds the train back into the system if it is possible. If the train has been added, the count of trains in the discharge area is reduced by 1. After all trains have been dealt with, the number of trains left in the loading area at the next cycle is compared to the allowed number. If the number is greater than allowed, the run is stopped. If it is equal to the number allowed, the discharge area is indicated filled for the next cycle by setting LIFILLD = 1. If it is less than number allowed, the discharge area is indicated ready for a train by setting LIFILLD = 0.

RAILEX - Extend Track

This routine handles extension of the track for the trains. If rail extension is stopped (NEXON = 1), the routine does nothing. Otherwise, NSWTCH is checked to determine whether the switch is already being moved. If not, the track extension needed is computed using either cyclic operations geometry (NGEO $\neq$ 1) or continuous operations geometry (NGEO = 1) which has been input by the user. If the computed advance of the track is not enough to allow the excavator to continue operating, then the excavator is turned off for the next cycle by setting LNBYBY = 1. Then there is a check to determine if a new switch needs to be added and/or the last switch needs to be pushed forward. If either of these need to be done, computations described below are done.

If at normal entry a switch was being moved or added, then time to move the switch and/or add a switch is decreased (computed if just beginning move or add) and the completion is scheduled when finished. In pushing the last switch forward, it is not marked as pushed forward until after the time to push it is finished. It is pushed either a distance equal to the excavator's progress in the cycle (DX) or by a distance preset by the user (AMAXL - AMINL). The latter distance will be used unless AMAXL = AMINL. If a switch is to be added, again it is not indicated as having been added until the time to add it is over. Then, the number of switches is updated and the position of the new switch is put just behind the position of the moveable switch which is always closest to the face.

Finally, a check is made to determine if a train should be added to the system since the rails have been extended. Distance from the portal in miles is computed and compared against user inputs which give NTMILP trains allowed before XP miles and NTMLPP trains allowed after XP miles. If the number of trains in the system is already equal to the number allowed, no train is added. Otherwise, ADDTRN is called if the discharge area is not filled. The new train, if ADDTRN allows it, is entered into the discharge area.

<u>RAILMT</u>

DT is added to the time since last maintenance TSTAT(I, 4) for each train I which is not unloading or already in maintenance. If for any train I, TSTAT(I, 4) is greater than the user input time between maintenance, the train is put into maintenance (if maintenance area is not full).

If a train I is already in maintenance, then its time in maintenance is decreased by DT. If this time has reached 0, the train is returned to the discharge area from the maintenance area and cost of maintenance is computed.

Finally, the number of trains in maintenance, NTMA, is compared to the user input maximum allowed trains. If too many trains are in maintenance an error message is printed and the run is stopped.

2. Type: Conveyor Belt

A set of four routines: TRNPRT, EXTNSN, SURGE, and BELT, simulates hauling muck to the discharge area by the conveyor. Each routine need be initialized only once at the start of the run. Initialization is done by setting ICYCLE to 1 before calling each routine. SURGE need never be initialized.

Common blocks:	COMMON/ALL/ COMMON/MONEY/ COMMON/PERFRM/ COMMON/NEWCOM/ COMMON/OLDCOM/ COMMON/CONVEY/
Input variables:	NAMELIST/BELTS/VBI, WP, AB, ACM, NGEO, SM, DTBS, QC, FL, XE, NSURGE, DWM, DTC, DTMB, EE, HP, FLM, SMIN, XLF, WBI, DMAINT
Status variables:	LMCAPC LNSURG LMACON LNSPLC LNBYBY FQL FSM

TRNPRT

Subroutine simulates the long haul of muck by conveyor belt to the discharge area. In a normal entry, loader capacity required for this time step is calculated. If this capacity WR is less than the available capacity WPCOMP, then muck is loaded and excess muck in the surge bin is taken out and loaded onto a belt. If WR is equal to WPCOMP, then muck is loaded. If capacity WR > WPCOMP, then it is determined if a surge bin has been provided. If not, the excavator is scheduled to be stopped on the next cycle (LMCAPC = 1). If a surge bin exists, the excess is loaded into it; then the surge bin is checked for overload. If it is overloaded, an excavation stop is scheduled on the next cycle (LMCAPC = 1).

In any case horsepower used is determined and job material cost DJMMH is incremented. Then the control program is executed.

EXTNSN - Extension of Conveyor Belt and/or Structure

This routine simulates extension of the conveyor belt (either extension of the structure and/or extension by a belt splice). In a normal entry, first a check is made to determine whether the extension is shut down (NEXON = 1). If it is, then a return to the control program is executed. If the extension is not shut down, a check determines if a structural extension is needed. If yes, the extension is carried out for whichever of the three geometries (NGEO = 1, 2, 3) (cyclic or one of two continuous) is being used; if it will be completed at the end of the time step, the end is scheduled by setting LNBYBY = 0; otherwise LNBYBY is set to 1. Another check is made to determine if a belt splice is also needed, and LNSPLC set to 1 if it is needed. Then the belt splice as described below is computed for the time remaining in time step.

If at normal entry a conveyor belt splice is going on, a check is made to determine if a surge bin has been provided. If a bin does not exist, the belt splice is simulated and the excavator is turned off if the splice is not complete at end of the time step (LNSPLC = 1). If a bin does exist, the excavator is turned off only if the surge bin becomes overloaded (LNSURG = 1).

BELT - Maintenance

This subroutine simulates maintenance of the conveyor belt. In a normal entry a check is made to determine whether maintenance is in progress (MACON = 1). If no maintenance is in progress then a check is made for which criterion is being used for maintenance, time (DTCB) or volume of muck loaded (DWM). For whichever criterion is being used a calculation is made to determine if maintenance is required. If maintenance is needed then it is scheduled for the next time cycle by setting LMACON = 1 and the subroutine does calculations for maintenance. If at entry maintenance was in progress, or if the belt has been put into maintenance, one time step is subtracted from maintenance time left and a check made to determine if maintenance is complete. If so, it is scheduled to end in the next cycle (LMACON = 0) and the cost of maintenance is added to the job materials costs DJMMH.

SURGE

This subroutine handled adding muck to and subtracting muck from the surge bin. It is called by the other conveyor belt routines if a surge bin exists (NSURGE = 1). It has one entry point SURGE for adding to the bin and one for subtracting, SURGE 2. When adding muck, a flag will be set to indicate overloading of the bin if this occurs (LNSURG = 1).

3. Type: Trucks

This set of routines simulates long haul of muck to the discharge area by trucks. The routines in the set are TRUKHL, RAILEX, TRUKDS, TRUKMT. TRUKHL is almost identical to RAILHL described in Sec. II-D-1 (see Vol. I of this report for exceptions). The routines TRUKEX, TRUKDS, and TRUKMT are actually the routines RAILEX and RAILDS described in Sec. II-D-1 with different entry points. Subroutine TRUKHL is identical to RAILHL with the exception of some coding to ensure that the truck stops before it hits the face. This coding is identified in the listing by comment cards. TRUKHL is the initialization entry point and TRUKTR is the normal entry point into the routine.

Common blocks:	Identical to those for rails
Input parameters:	NAMELIST/TRUCKS/parameters are identical to those for rails
Status variables:	Identical to rails

E. ELEMENT: GROUND SUPPORT

1. Type: Rock Bolts, Shotcrete, Steel Sets, and Combinations of These

Unlike other elements which have a different set of routines for each type, all ground-support types are handled in one set of subroutines (GRNSUP, GSMAIN). Ground support frequently uses combinations of support types, making it more efficient to put all types in one set of subroutines. The decisions about type of ground support to be used for each geology during the simulation are made with the aid of a primary ground-support table (stored in array PSST). This table may be input by the user, or the default table (Table IV-1) will be used. Any primary ground-support table gives the major and minor support types and their spacing (or thickness) for different rock fragmentation methods (JMETH), and for ranges of rock densities (RDQ). For instructions on inputting the default table, see below.

Common blocks: COMMON/ALL
COMMON/PERFRM/
COMMON/MONEY/
COMMON/OLDCOM/
COMMON/NEWCOM/
COMMON/GRND/

Status variables: LMGS(5)
LIEXCA

Input variables: NAMELIST/GROUND/USC, UCSC, RATERB, RATESC, GSETDO RATESS, MAXPSS, ERBDRI, GDOW, ESCPLA, DJMGS, GMEN, GCST

A set of cards must be input for the ground support if MAXPSS $\neq$ 0 in the set of cards described above. In this case the user is indicating that he wishes to input his own primary ground-support table in preference to the default table (Table IV-1). See INPUT routine written for the Layout Tunnel for an example of one method of reading in these cards. A sample set of cards is shown in Fig. IV-3. The value of MAXPSS in the set of cards above should be equal to the number of these cards. The columns on the cards correspond to the columns in Table IV-1. These data cards are the last set of input cards for the model, and cards should be ordered such that the RQD column is decreasing on successive cards. The cards give the type of support that will be used for various ranges of

TABLE IV-1

PRIMARY GROUND SUPPORT

(Default Values Are Shown)

ROD	EXCAVATION PROCESS	UNSUPPORTED LENGTH-MAXFT	INTERFERENCE LENGTH FT	SUPPORT TYPE	SPACING FT	THICKNESS IN	CROWN AND/ OR SIDES	ADDITIONAL SUPPORT
95.00	5.00	999999.90	0.00	1.00	0.00	0.00	0.00	1.00
90.00	5.00	999999.90	0.00	1.00	0.00	0.00	0.00	1.00
90.00	2.00	10.00	0.00	3.00	0.00	5.00	0.00	1.00
75.00	5.00	8.00	0.00	3.00	0.00	1.00	0.00	1.00
75.00	1.00	8.00	4.00	3.00	0.00	1.00	0.00	1.00
75.00	2.00	5.00	0.00	2.00	5.00	0.00	0.00	1.00
50.00	5.00	6.00	0.00	3.00	0.00	3.00	0.00	1.00
50.00	1.00	6.00	4.00	4.00	3.00	0.00	0.00	1.00
50.00	2.00	4.00	0.00	4.00	4.00	0.00	0.00	1.00
25.00	5.00	5.00	0.00	3.00	0.00	5.00	1.00	2.00
25.00	1.00	5.00	4.00	4.00	3.00	0.00	0.00	2.00
25.00	2.00	3.00	0.00	4.00	3.00	0.00	0.00	1.00
0.00	5.00	2.00	0.00	4.00	2.00	0.00	0.00	1.00
0.00	1.00	2.00	4.00	4.00	2.00	0.00	0.00	1.00
0.00	2.00	2.00	0.00	4.00	2.00	0.00	0.00	1.00

NOTE. EXCAVATION PROCESS =5 INDICATES ANY PROCESS OTHER THAN THOSE IN TABLE rock RQD and type of rock fragmentation. Each card input gives a major and additional support type to be used for one rock excavation process, and any rock RQD greater than or equal to the one on the card but less than the one on the previous card.

The codes for the rock excavation type to be put on the card are as follows:

Rock Excavation Type	Code
Boring machine	1
Drill and blast	2
Water jet	3
Projectile	4
To be used if actual type is not in table	5

The codes for support types and additional support types are as follows:

Support Type	Code
None	1
Rock bolts	2
Shotcrete	3
Steel sets	4
Lagging	5

The other parameters on each card are as follows:

1. Unsupported Length - Maximum Feet
   This is the maximum number of feet from the heading that ground support can be before the excavator must be turned off to allow ground support to catch up.

2. Interference Length - Feet
   Number of feet that must separate ground support and the heading. Ground support will not be allowed closer to the face.

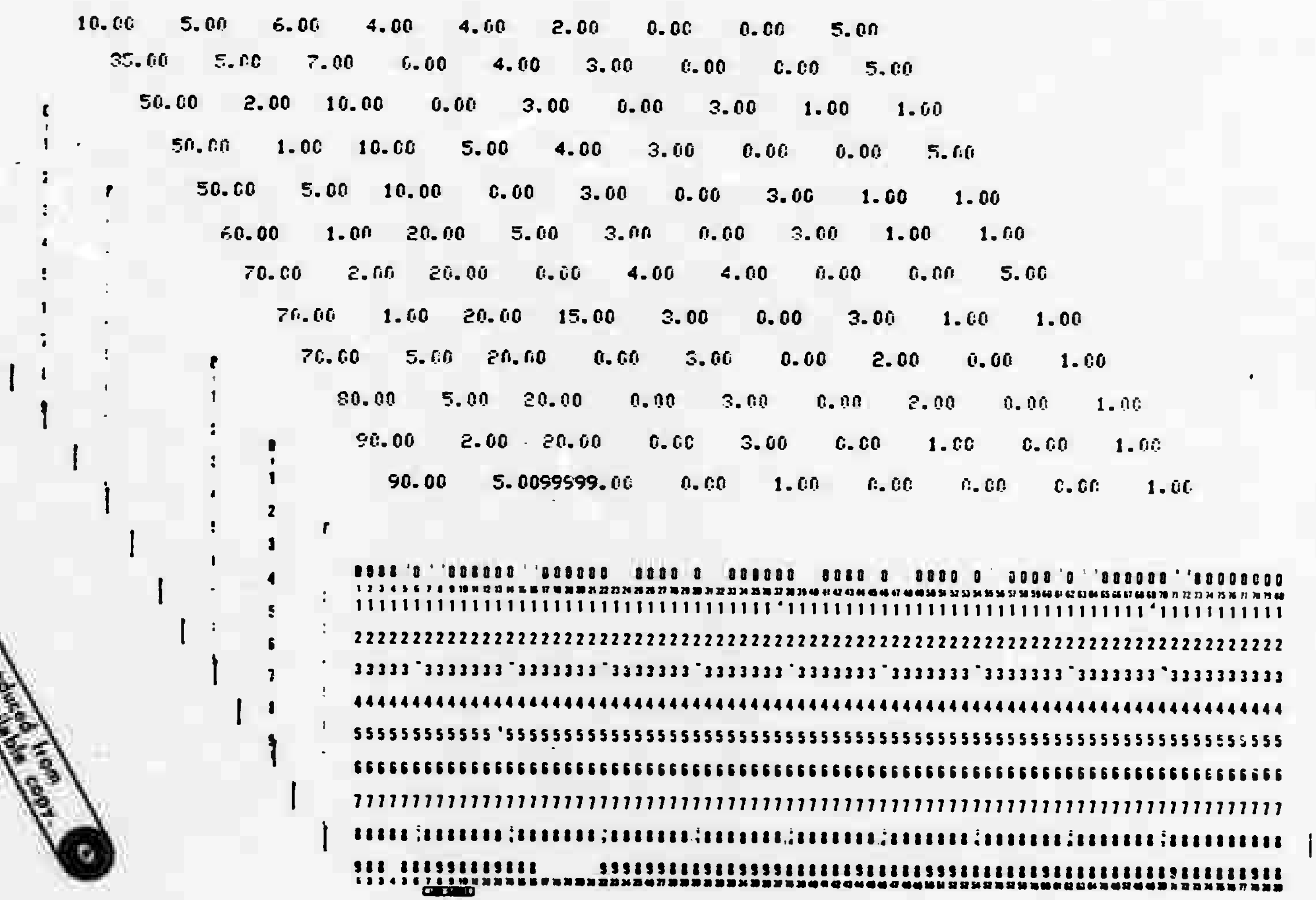


Figure IV-3. Example, Ground-Support Input Cards

3. Spacing - Feet

   This will be $\neq 0$ only if rock bolts or steel sets are being used as support or additional support. It gives the spacing between rock bolts or steel sets.

4. Thickness - Inches

   This is the thickness of the shotcrete to be installed and is $\neq 0$ only if shotcrete is being used.

5. Crown and/or Sides

   This is $\neq 0$ if shotcrete not being used or if only crown is to be covered. If crown and sides are to be covered it is =1.

GRNSUP - Ground-Support Installation

In a normal entry (ENTRY GROUN), ground support, using the rock density (RQD) and the rock fragmentation method, computes the ground-support parameters for this time step from the primary ground-support table (PSST). Checks are made to determine the ground-support status and position with respect to the face of the tunnel. Labor time used is incremented. For each type of support being used the amount of material needed is computed. The cost and advance of ground support is calculated (either actual or lost due to idleness or maintenance). Finally, operating time and plant and equipment costs are incremented.

GSMAIN - Ground-Support Maintenance

A normal entry to this routine (ENTRY GSMNT) first determines if a combination of types is being used. If yes, then the time step is divided by 2. Then for each of the five ground-support types it asks if the type is being used. It then asks if the type (in use or not) is in maintenance.

If the type is in maintenance, the maintenance time remaining for the type is reduced by one time step and if no time remains it is marked to be removed from maintenance in the next time step.

If the type is not in maintenance and not in use the next type is looked at. If it is not in maintenance and in use, then one time step is subtracted from the time remaining before maintenance. If the time remaining is ≤ 0, the ground-support type is marked to be put into maintenance for the next time step.

F. ELEMENT: ENVIRONMENTAL CONTROL

1. Type: Ventilation, Cooling Plant, and Water Removal

One subroutine (ENVIR) simulates the environmental control. The environmental element is assumed to need no maintenance and to always be operating. It is assumed also to not interfere with other elements in the tunneling process and therefore has no status variables.

Common blocks:	COMMON/ALL/ COMMON/PERFRM/ COMMON/MONEY/ COMMON/ENVC/
Input variables:	NAMELIST/ENVIRC/EVENTP, MAXMEN, TDTHP, QM, QD, VAMIN, VAMAX, TA, TD, WA, FKD, FKT, CPA, CKA, REFRAT, PR, AMC(10), CAVMP

ENVIR

In a normal entry (ENTRY ENVIRC) labor time used, plant and equipment costs, and operating time are incremented. Next the cost of pumping water is computed. Then the amount of heat added to the air from various sources is computed; then the velocity of air is checked if more cooling is needed. Finally, the amount of cooling and ventilation needed in this time step are calculated. Cost of cooling and ventilation are added to job materials costs for environmental control DJMEC.

G. INPUT ROUTINE

This subroutine was written for the Layout Tunnel (see Vol. I). It is described here as a sample of possible way of initializing data in the model. It can easily be modified and used with any control program written to model other excavation systems. The routine is called at the beginning of a run and will read in the input cards for the subroutines and initialize the geology parameters by reading in the first geology record. It has two entry points, INPUT AND INPUT 2.

Common blocks: All common blocks that the control program contains.

ENTRY INPUT Reads in cards and starts geology file.

First cards are read and their images written onto tape (LOGICAL unit 5 in present control program; see listing of INPUT in Appendix II), card images being printed out. When an end-of-file is encountered, tape 5 is rewound.

After the rock fragmentation and materials handling methods have been read in from the first card image, tape 5 is read by the various NAMELISTs. Note that the card sequence of NAMELISTs must be the same as the reading sequence because the READ statement will search through the NAMELIST images on tapes for the first one to be read and then search subsequent ones for the next, and so on. Therefore if NAMELIST BORE appears on the cards before GENERL, BORE will never be read because in INPUT, BORE is read after GENERL.

After all NAMELISTs which were found on tape 5 have been read and printed out, the first record on the geology file is read. This is not necessarily the starting point in the tunnel for the model but merely starts the geology file. (This file is described in Appendices II and III.) Then the cross section of the tunnel is computed and the local variables used to read in train status, position, speed, and maintenance times are set into a global array TSTAT(J, K) (equivalent to ITSTAT (J, K)). From train status it is also determined which, if any train is available for loading. Finally, if a primary ground-support table is to be read in (MAXPSS $\neq$ 0), it is read from cards in fixed format (see listing of INPUT in Appendix VI).

ENTRY INPUT 2

This routine is entered at this entry point after all subroutines included in the run have been initialized. Variables which can be initialized (those on NAMELISTs) are again printed. Those that were undefined by the user will have been given default values by the individual routines. See Appendix VI for a sample printout of the routine.

H. OUTPUT ROUTINES

These four routines, OUTPUT, REPORR, REPORC, and MAXADV, were written for the Layout Tunnel. Two of the routines produce the interim reports using variables which are computed in the element subroutines. A third prints out the working storage common variables necessary for restarting the model at an intermediate point in the tunnel. Finally, a fourth routine computes the advance each day and retains the maximum daily advance. These routines may be easily modified and used with another control program to produce output. The last three routines, REPORR, REPORC, and MAXADV, may be used without modification if the notes in Sec. III of this appendix are followed.

Common blocks: (for OUTPUT) All common blocks in control program
(for REPORR, REPORC, MAXADV) COMMON/ALL/
COMMON/MONEY
COMMON/PERFRM/
COMMON/LABOR/
COMMON/TEST/

Input variables: Contained in NAMELIST/GENERAL
REPORT, DTPRNT

OUTPUT

This routine must be modified by the user if he is simulating tunneling with different methods than those in the sample program.

It is essentially a printout of selected variables in various common blocks which give the user a picture of the status of the tunneling elements at intervals during a simulation and at the end of a run. It should contain the variables needed to restart the model.

At present it prints, besides general variables, status variables for the boring machine, integrated conveyor loader, rails, and ground support. These are the processes being used in the sample tunnel, and the variables needed to restart the tunneling at any time or heading.

MAXADV

The advance per operating hour is computed for the past 24 hours elapsed time. If it is greater than the maximum advance already saved, then it becomes the maximum advance and is retained as such.

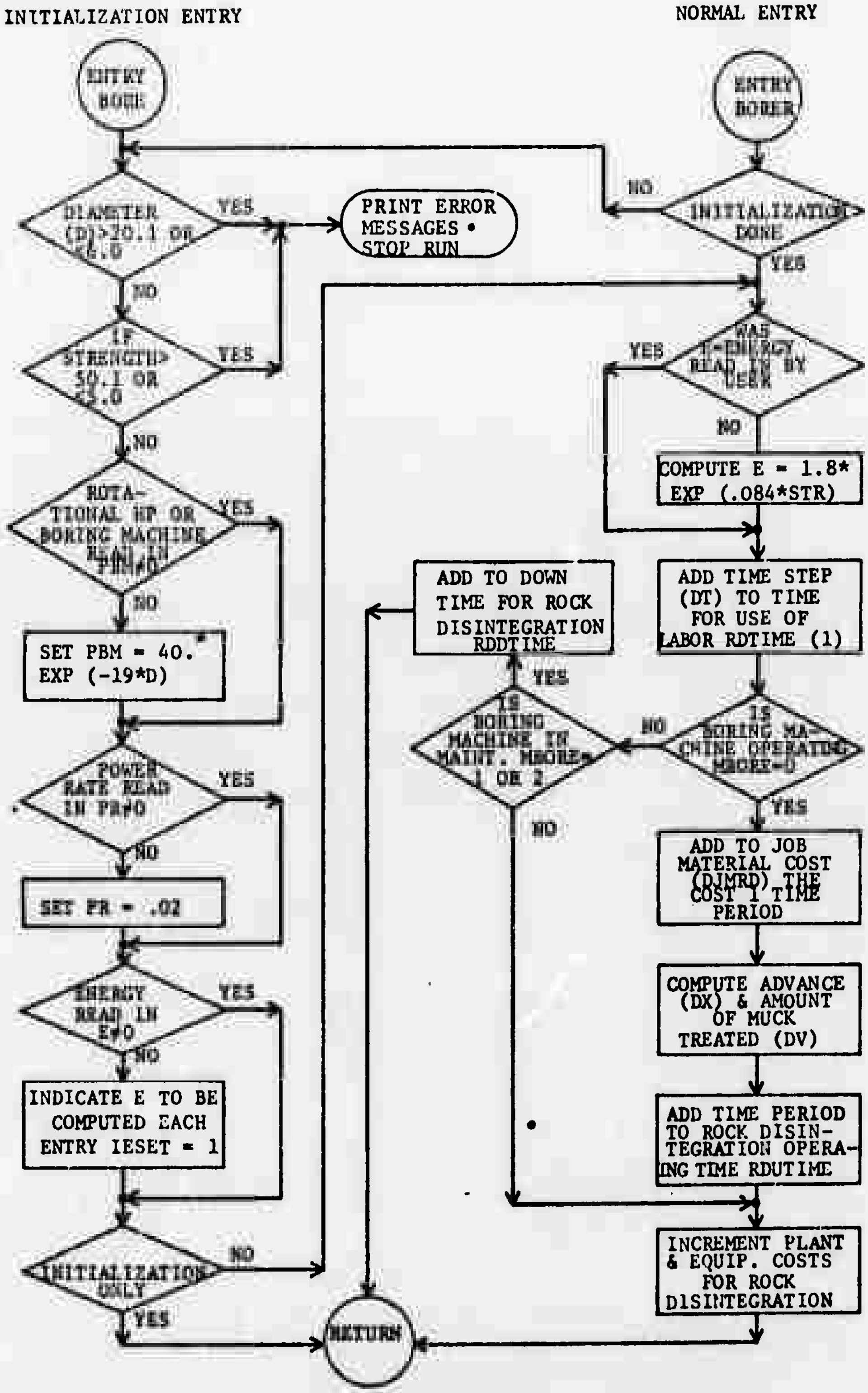
REPORR

This routine prints out the interim performance reports giving cumulative time, advance, (since beginning of this run) and heading position, maximum daily advance values, (since beginning of run) and utilization and availability figures for each general process.

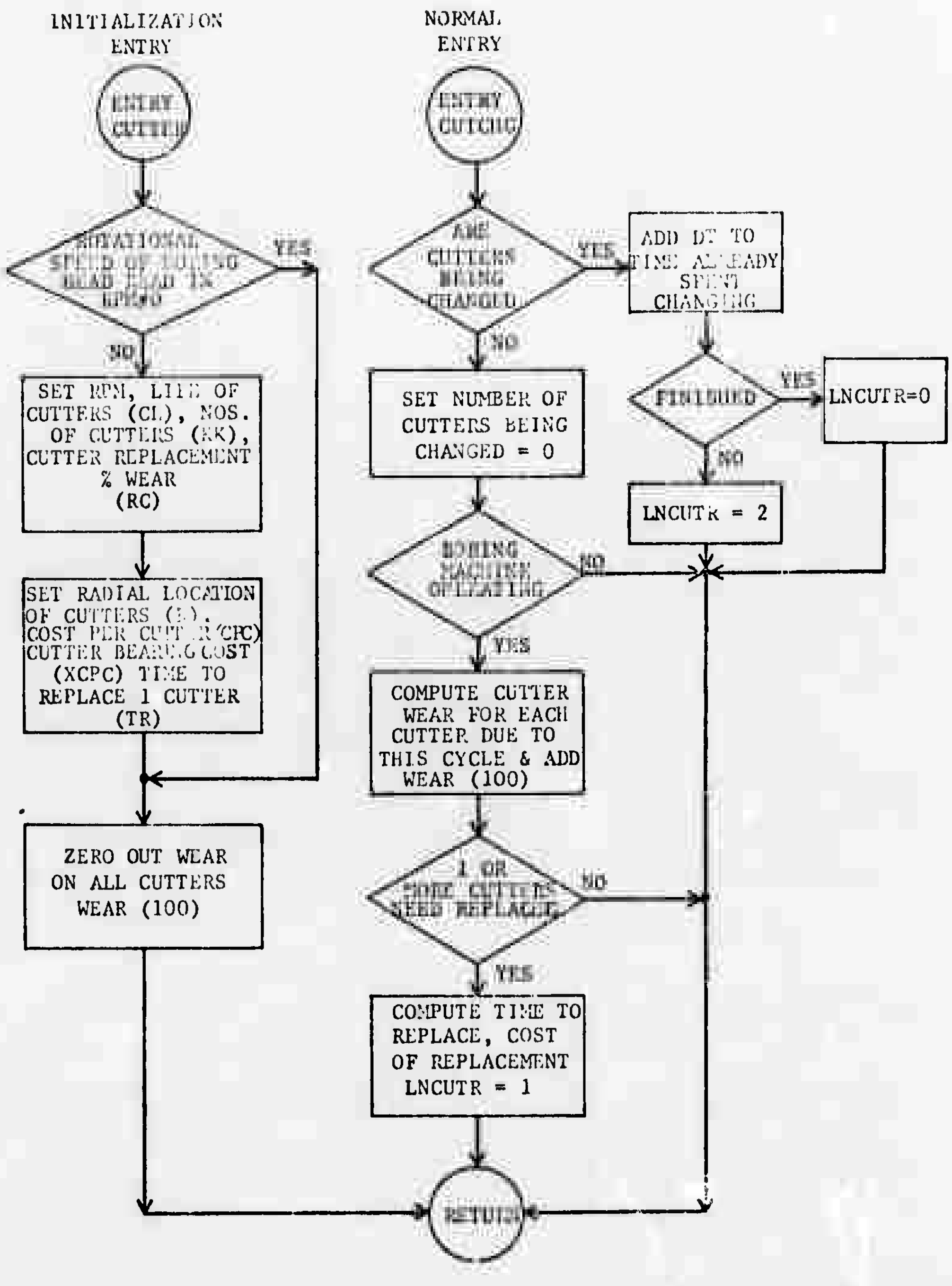
REPORC

Routine prints out cumulative costs since beginning of run. Total costs and costs for each general process are printed out.

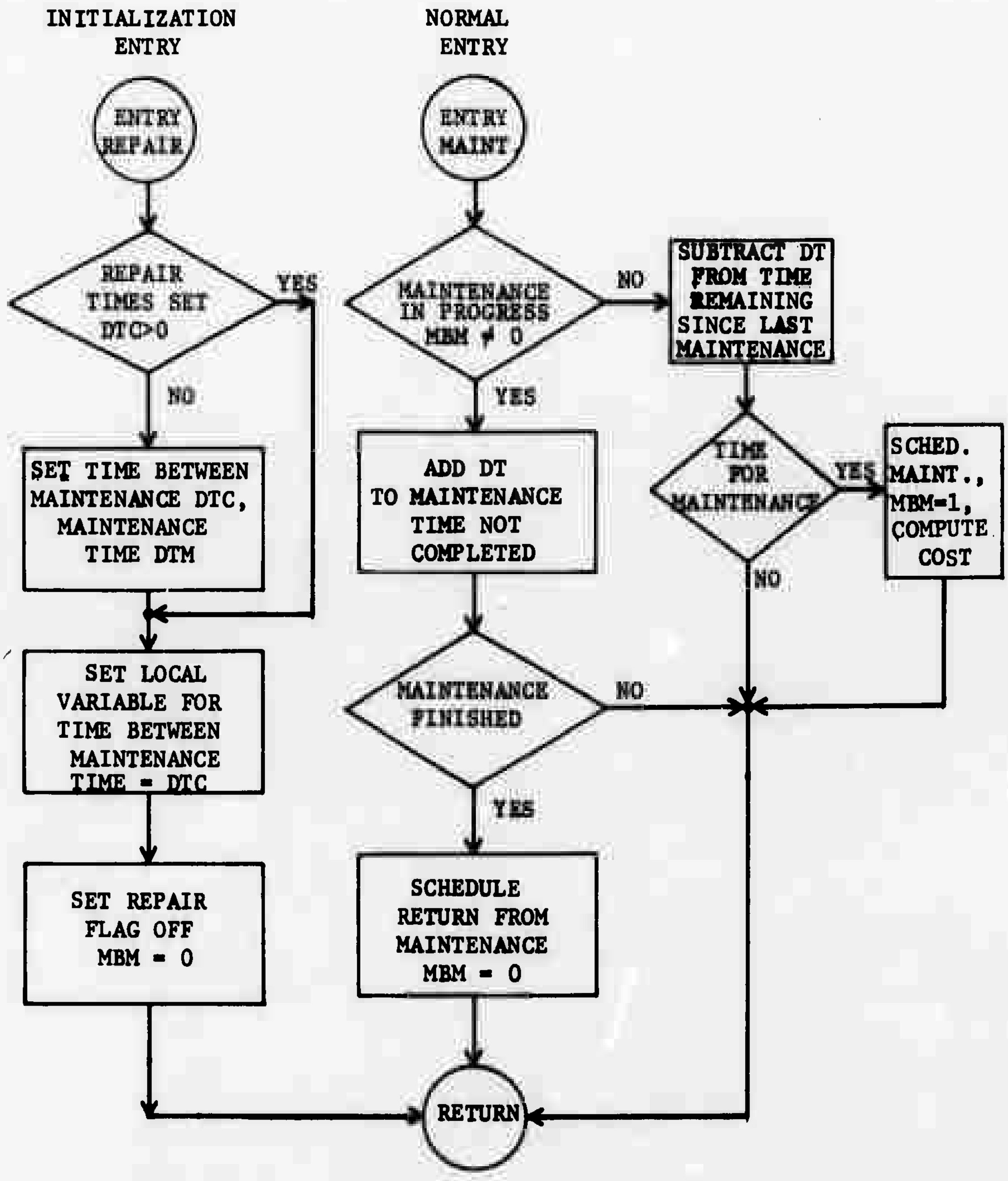
Subroutine BORE



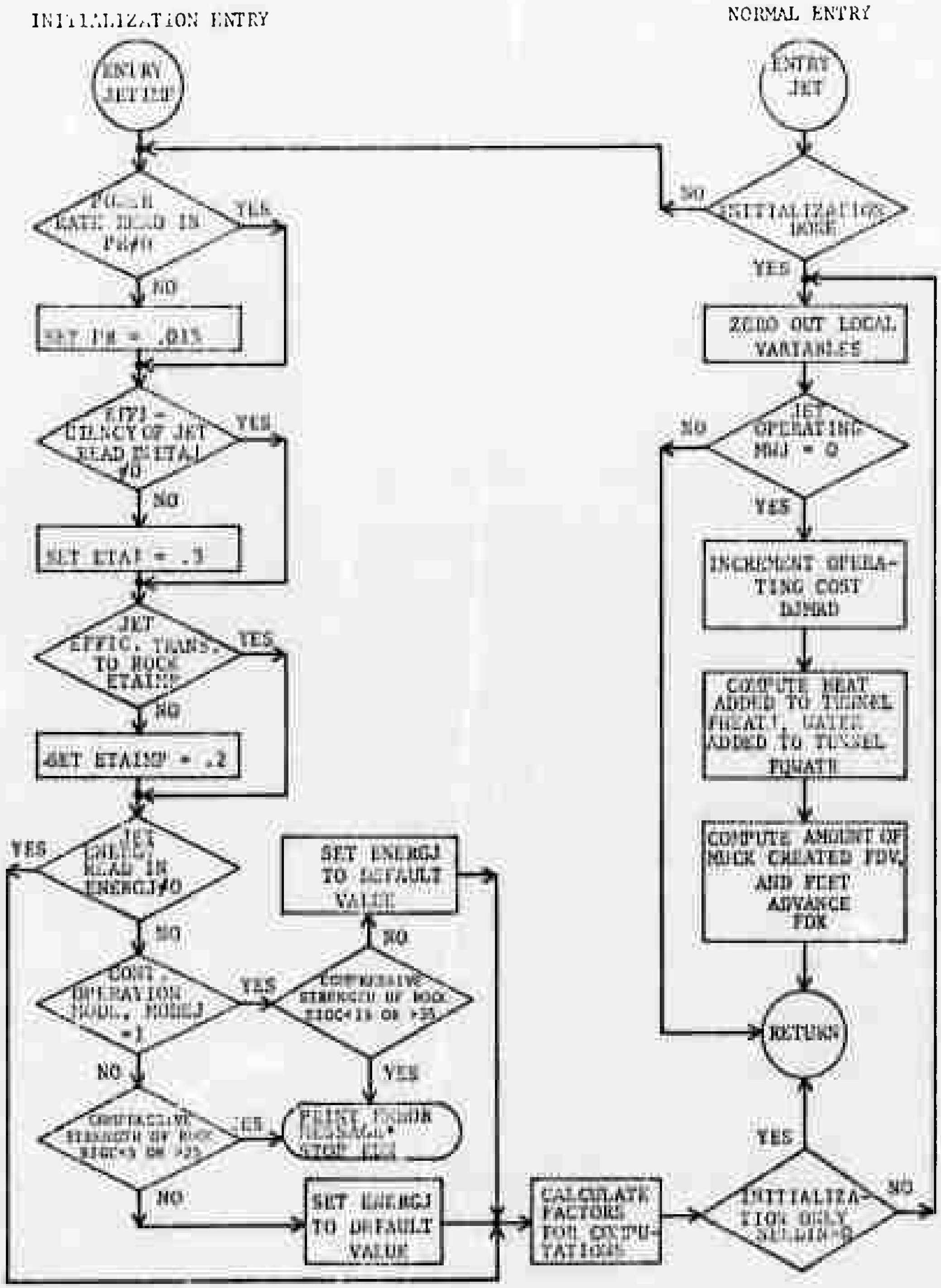
Subroutine CUTTER



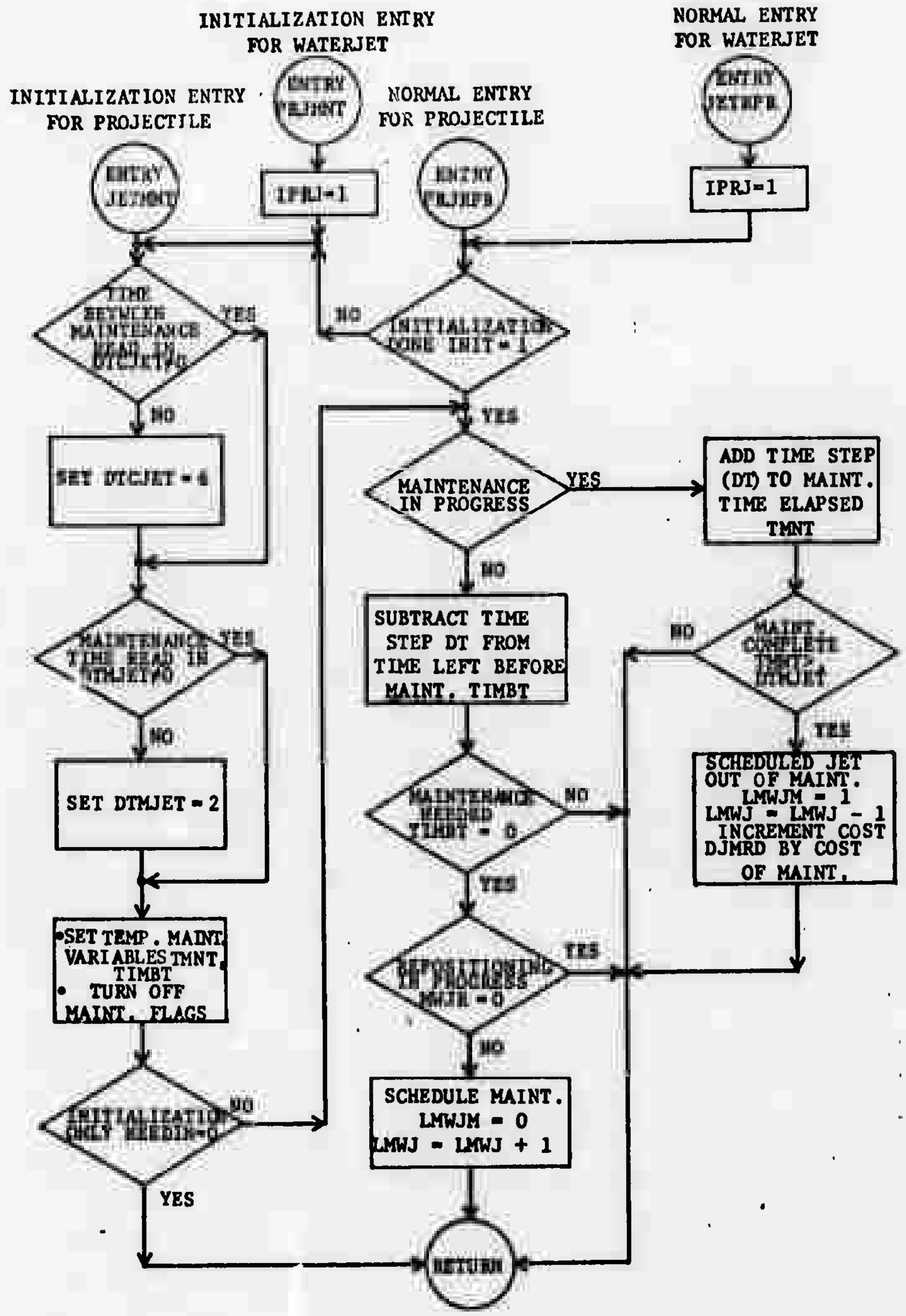
Subroutine REPAIR



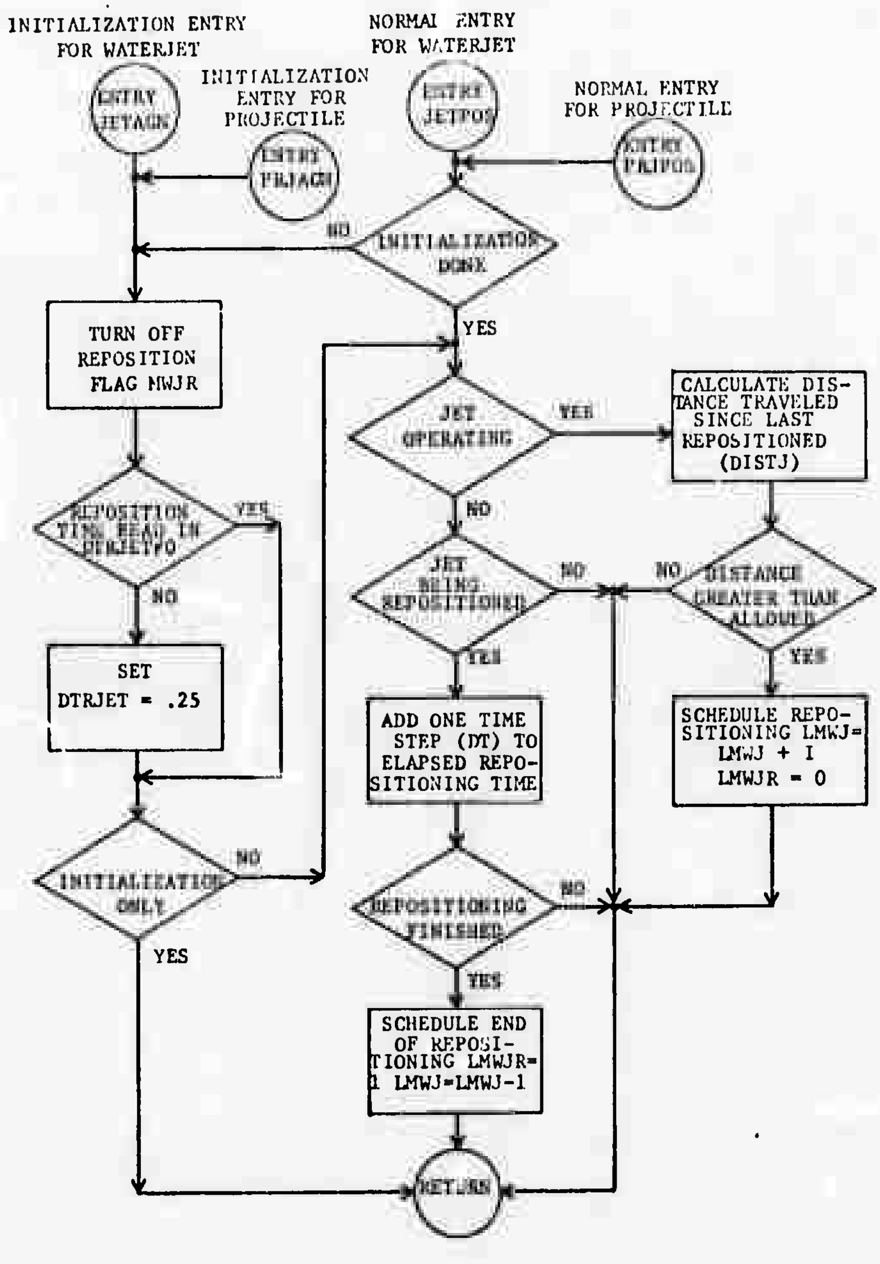
Subroutine JETIMP



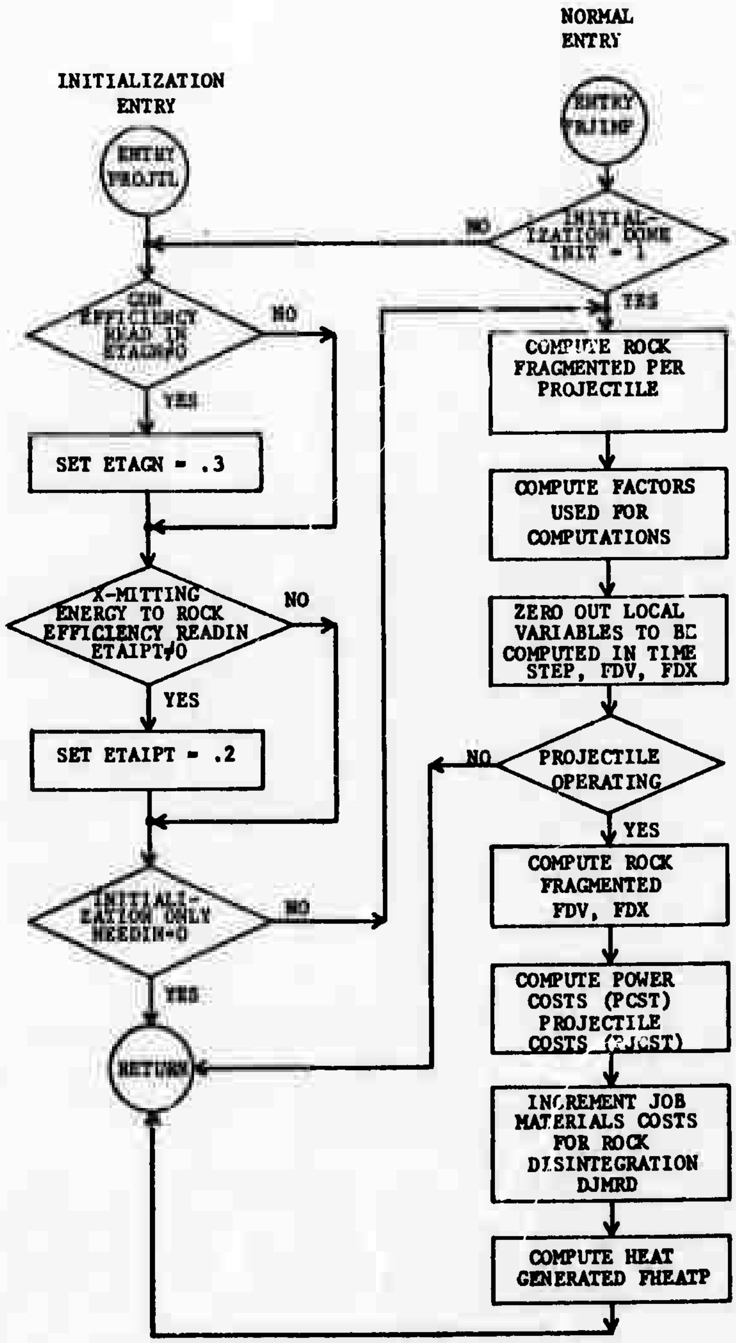
Subroutine JETMNT



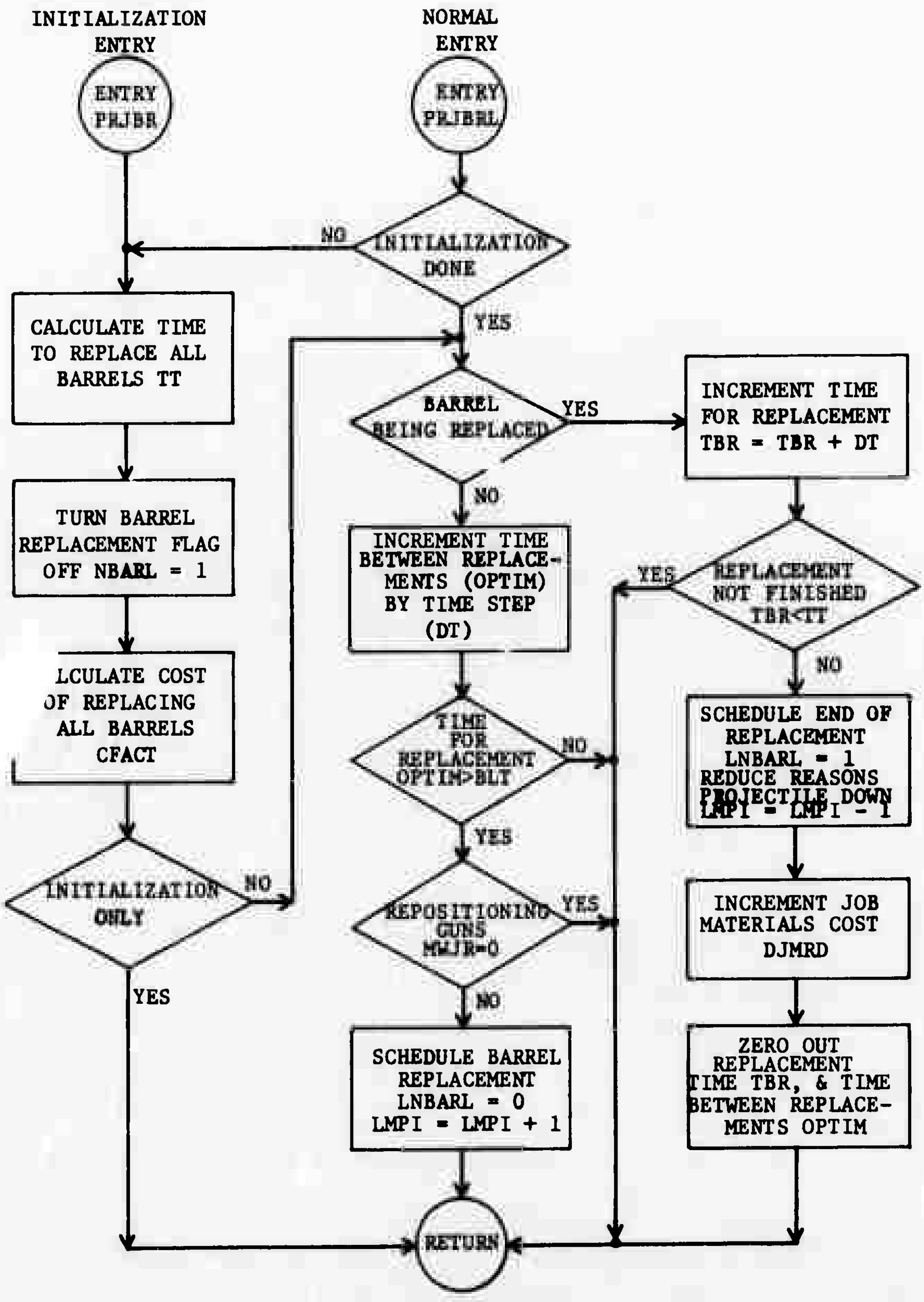
Subroutine JETAGN



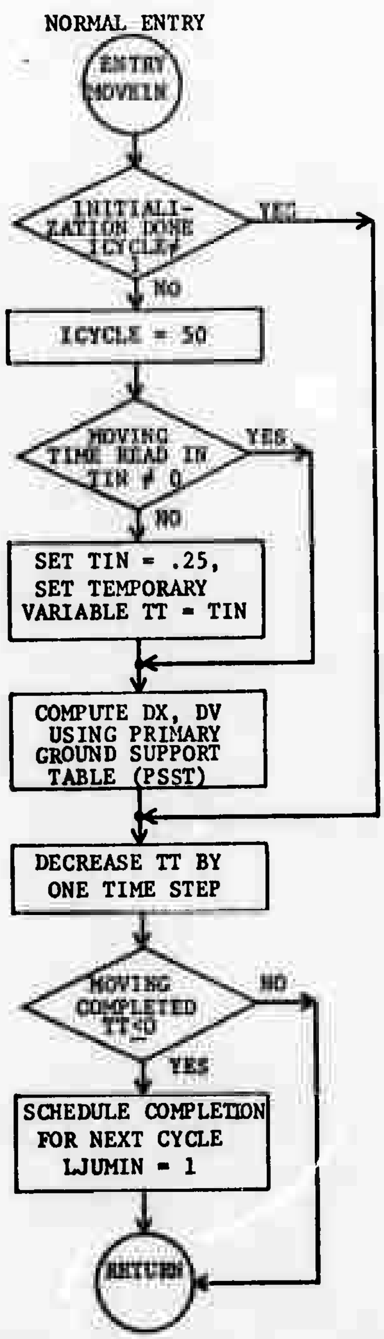
Subroutine PROJTL



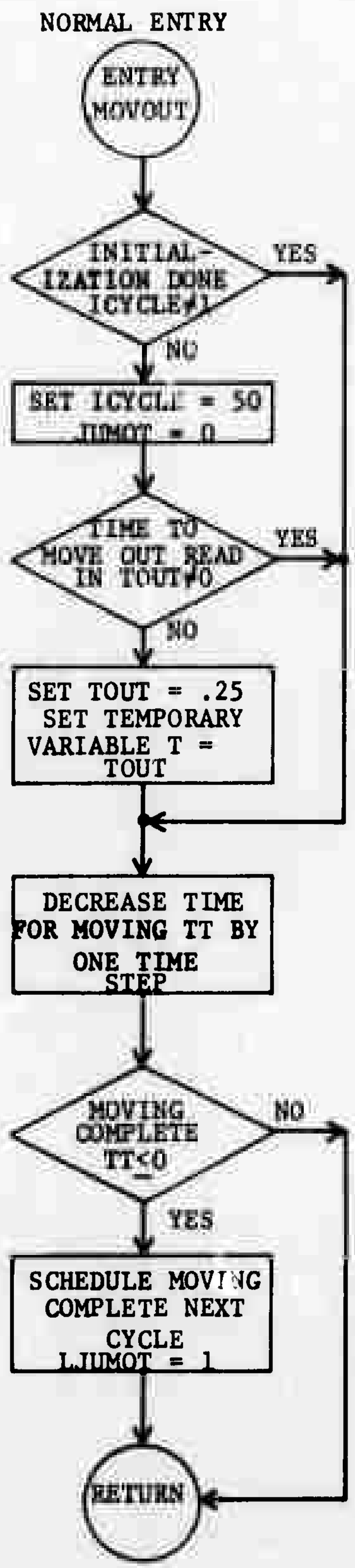
Subroutine PRJBR



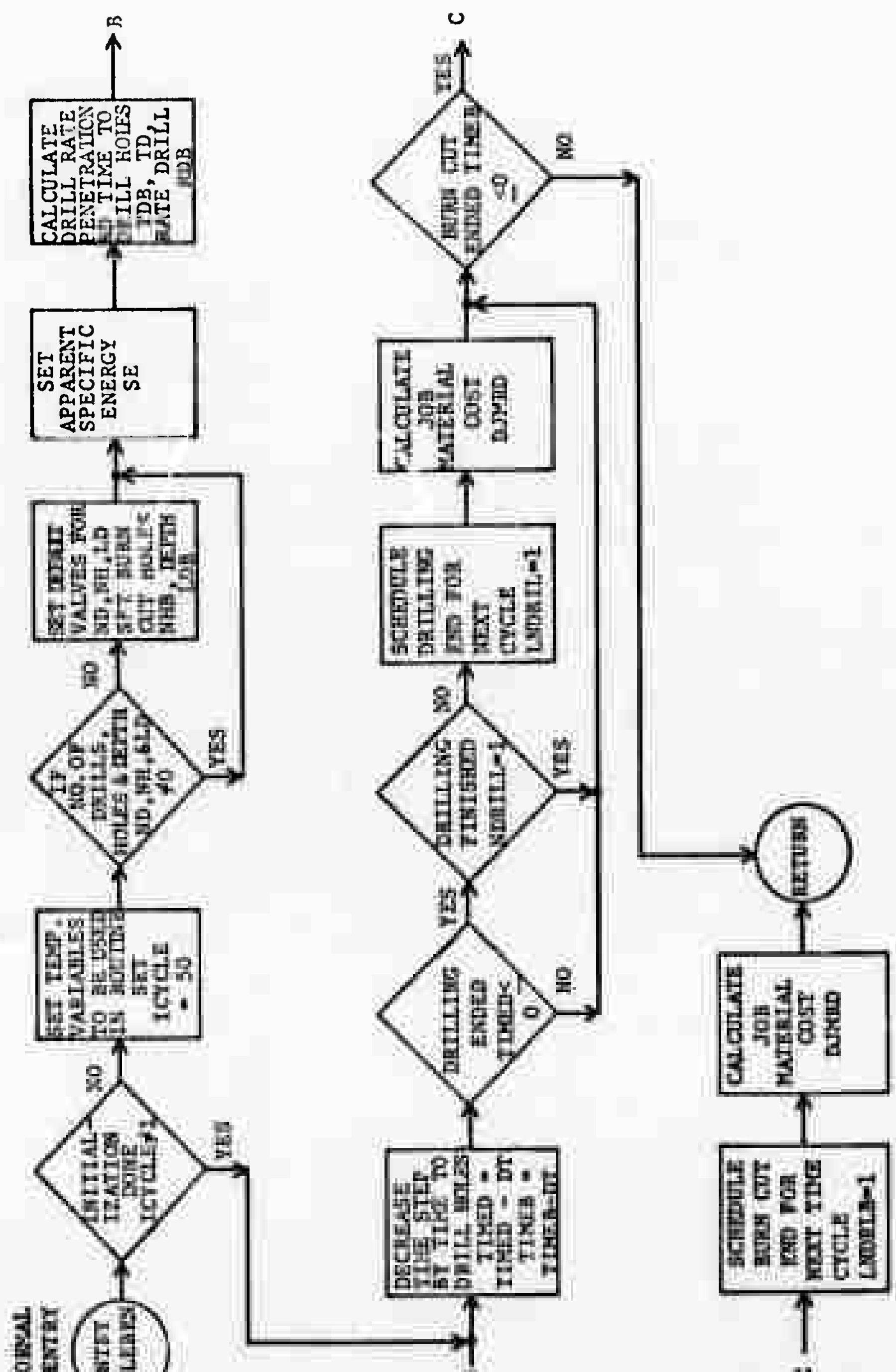
Subroutine MOVEIN



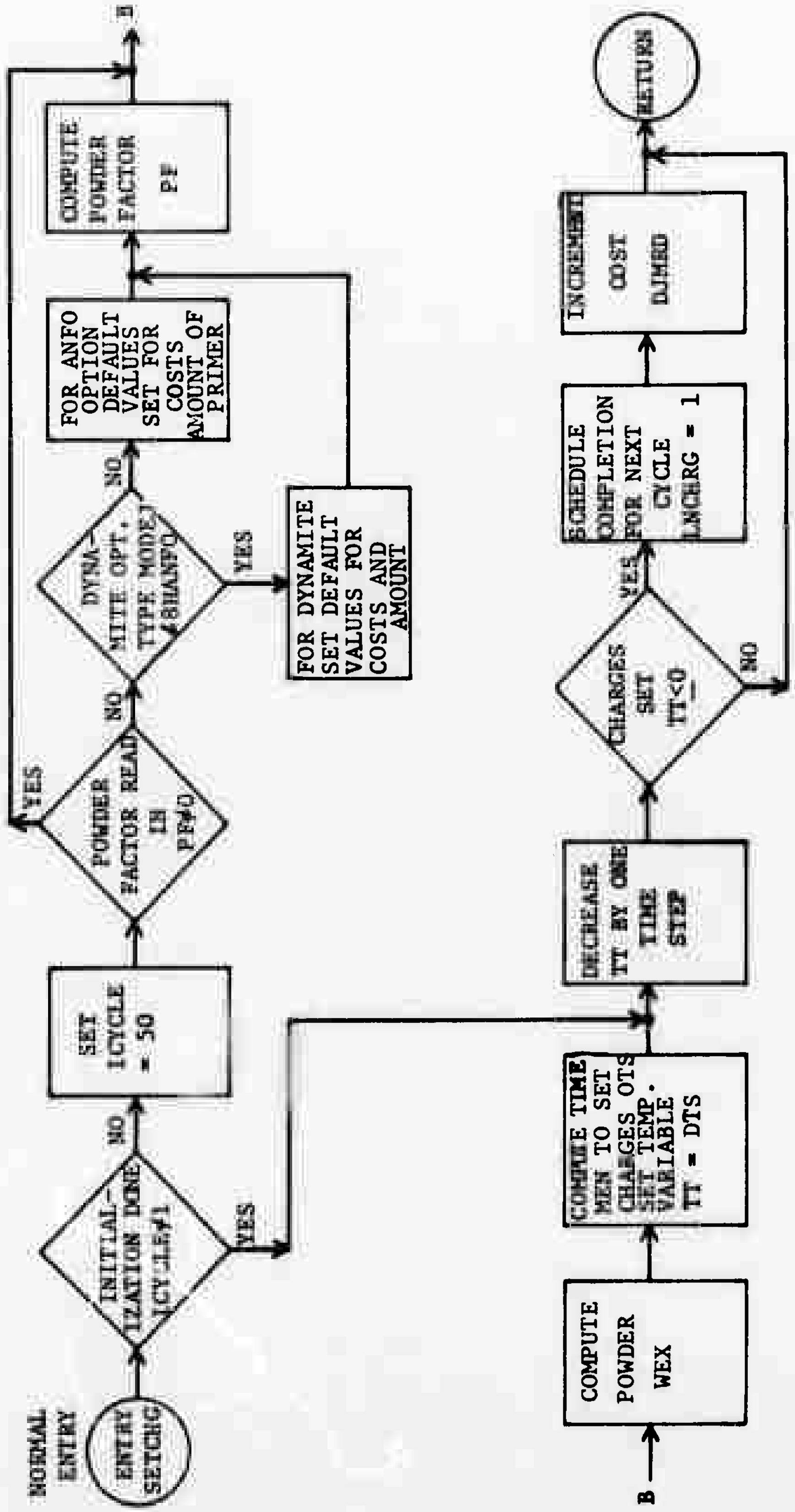
Subroutine MOVOUT



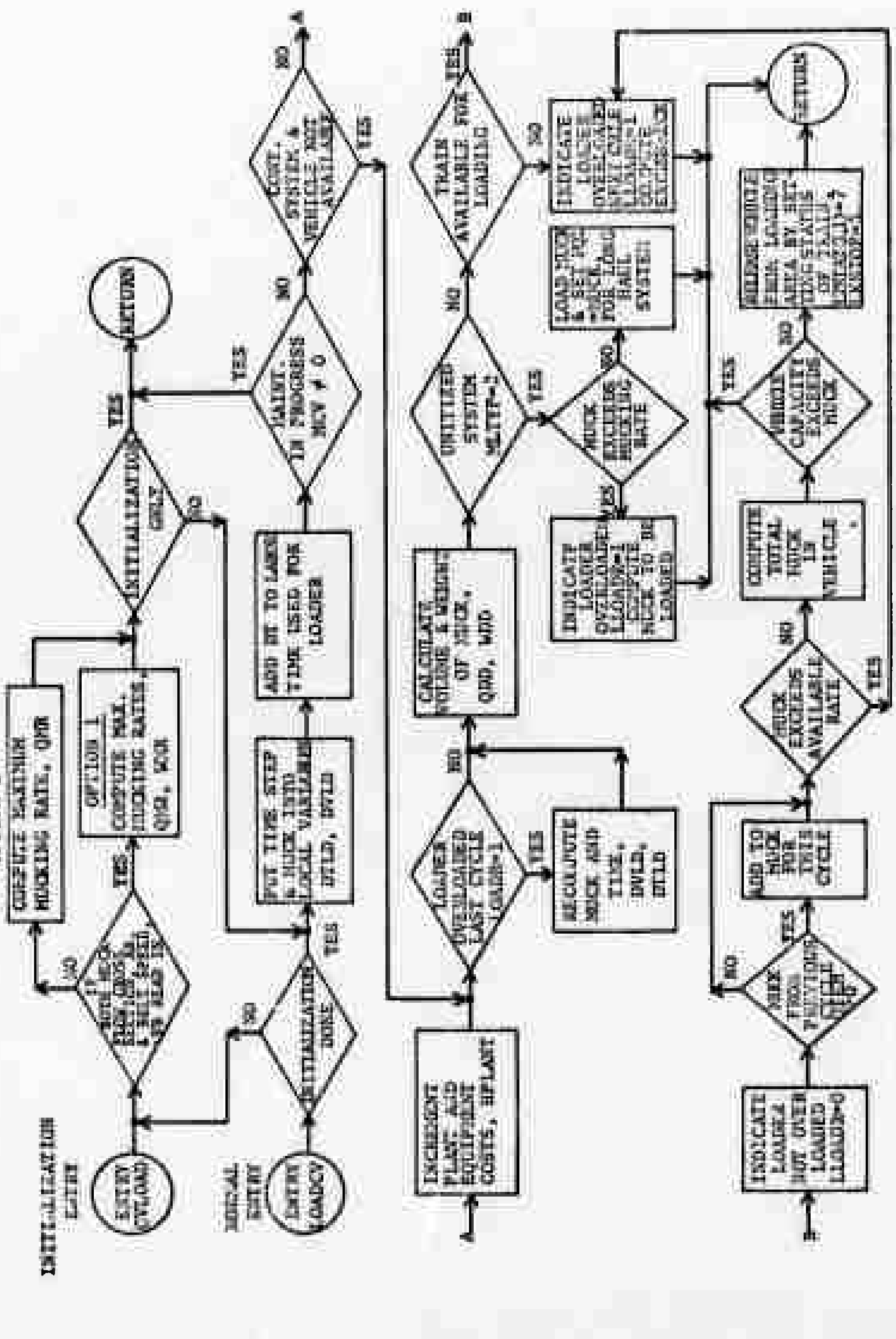
Subroutine HOLBRN



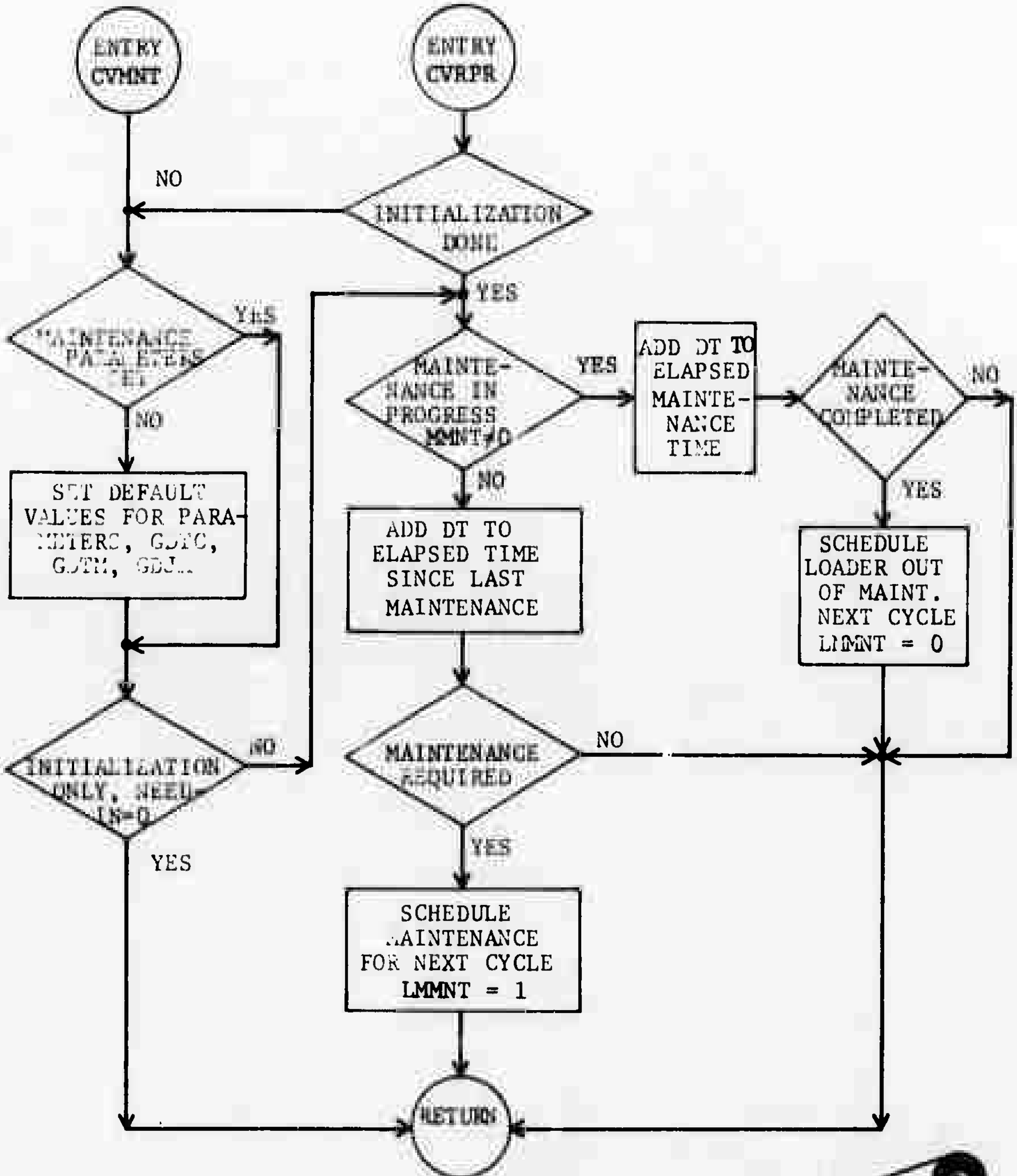
Subroutine SETCHG



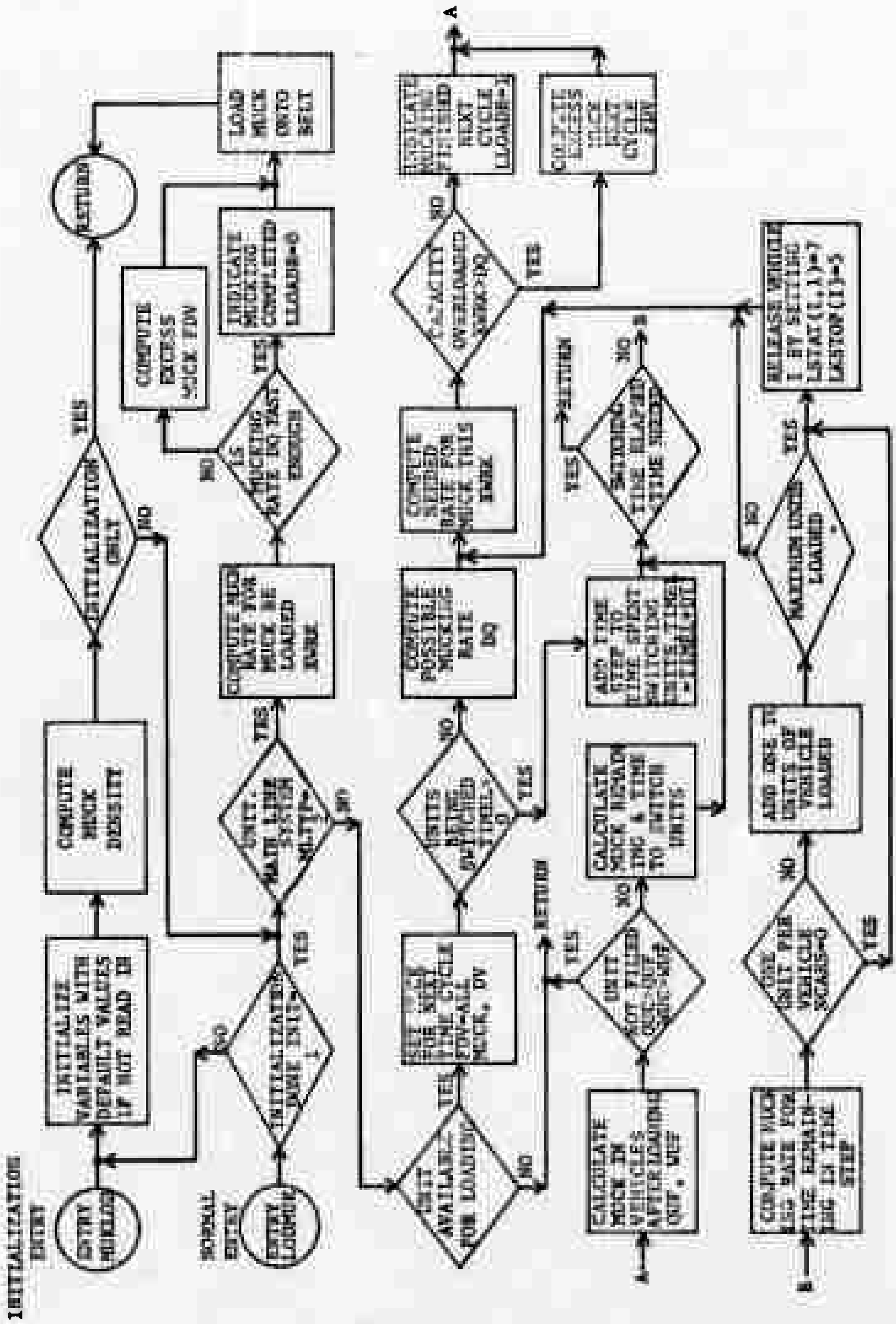
Subroutine CVLOAD



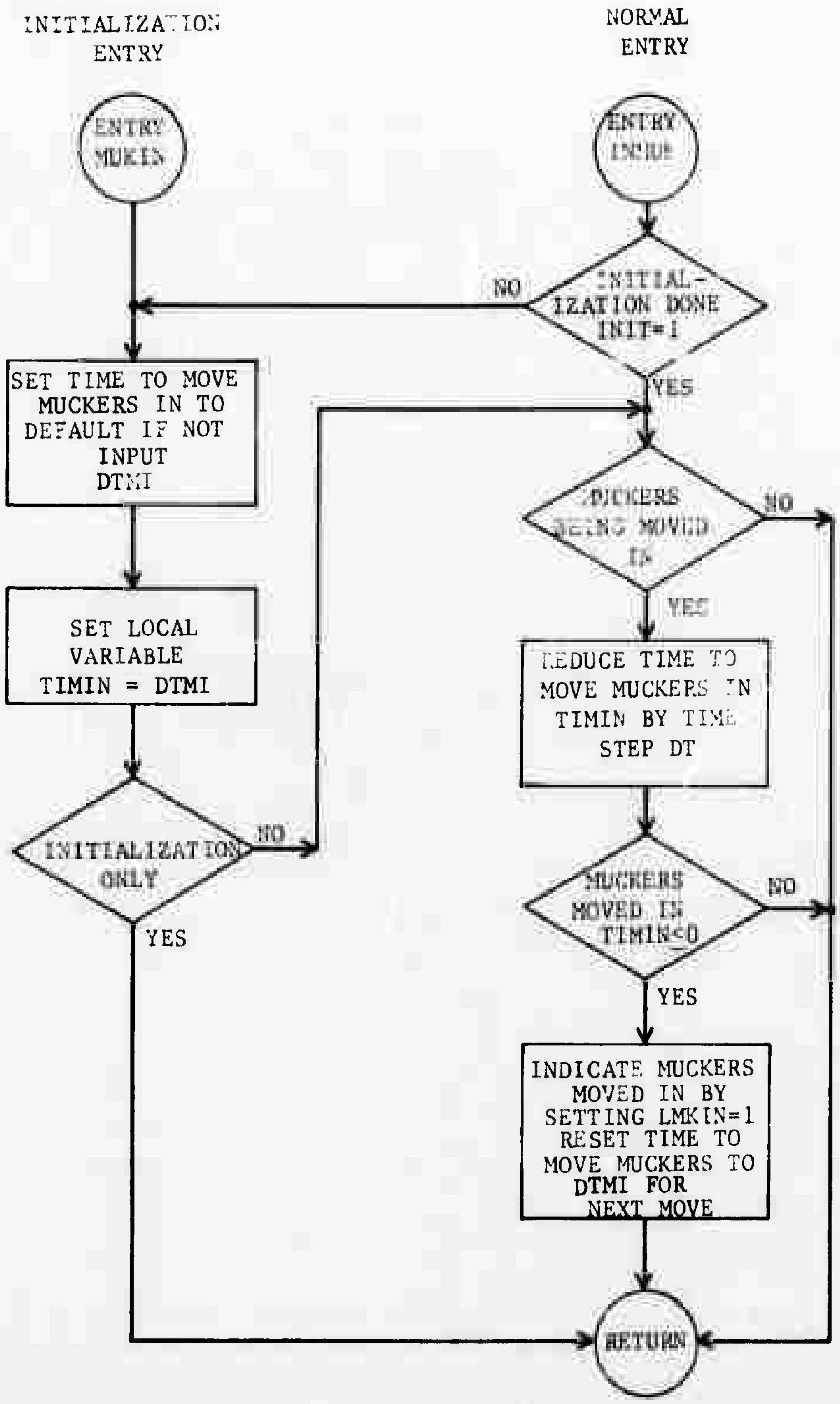
Subroutine CVMNT



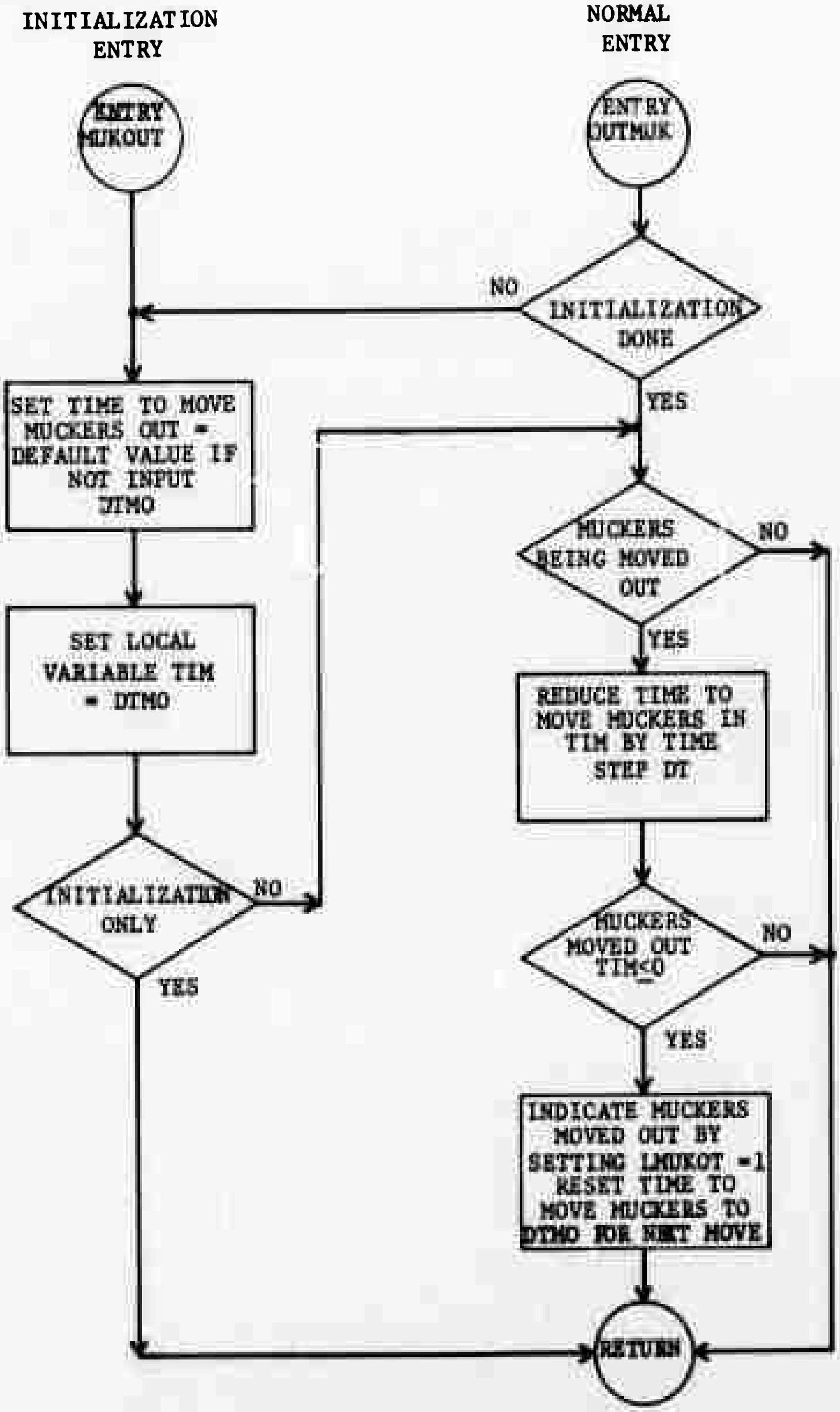
Subroutine MUKLOD



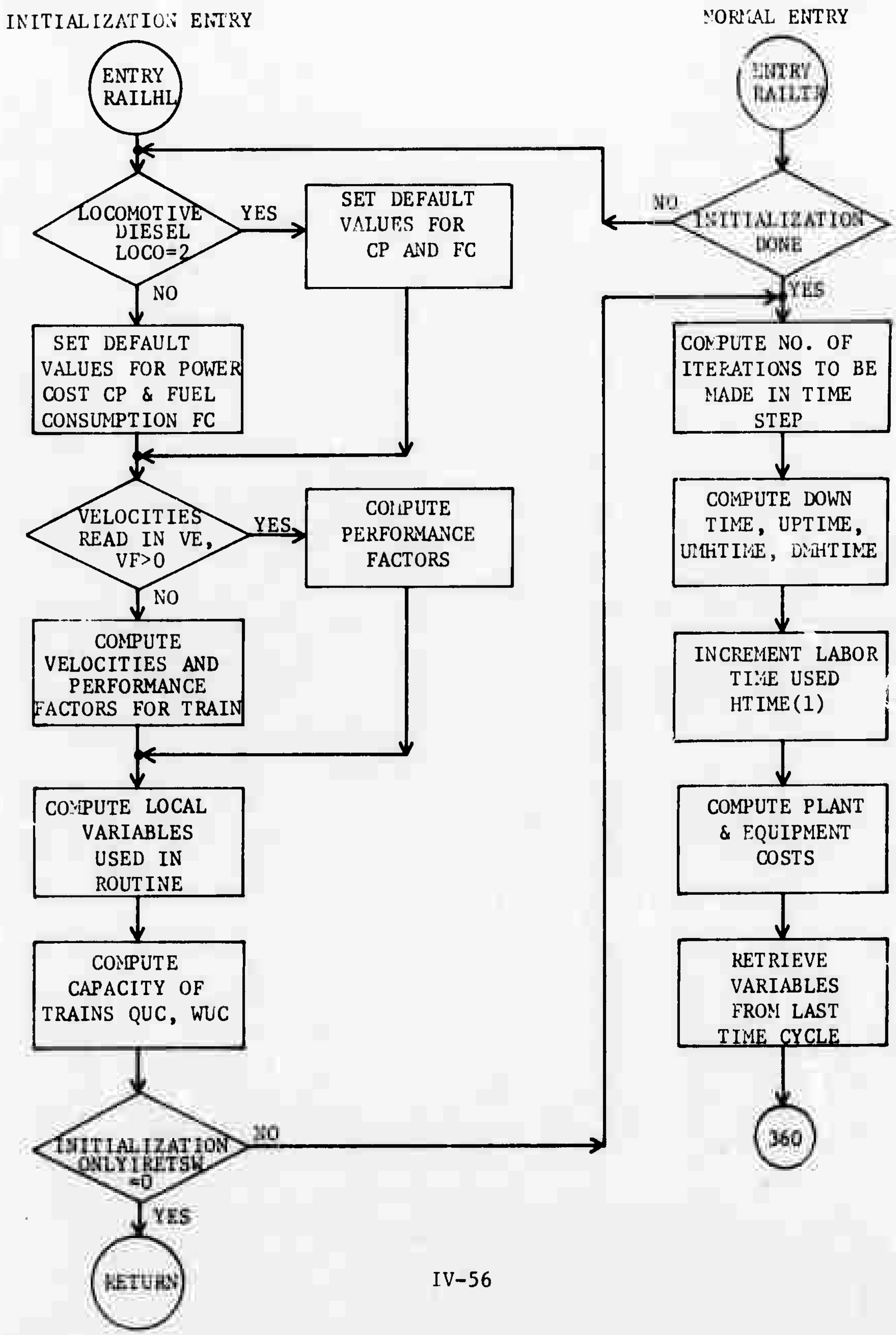
Subroutine MUKIN



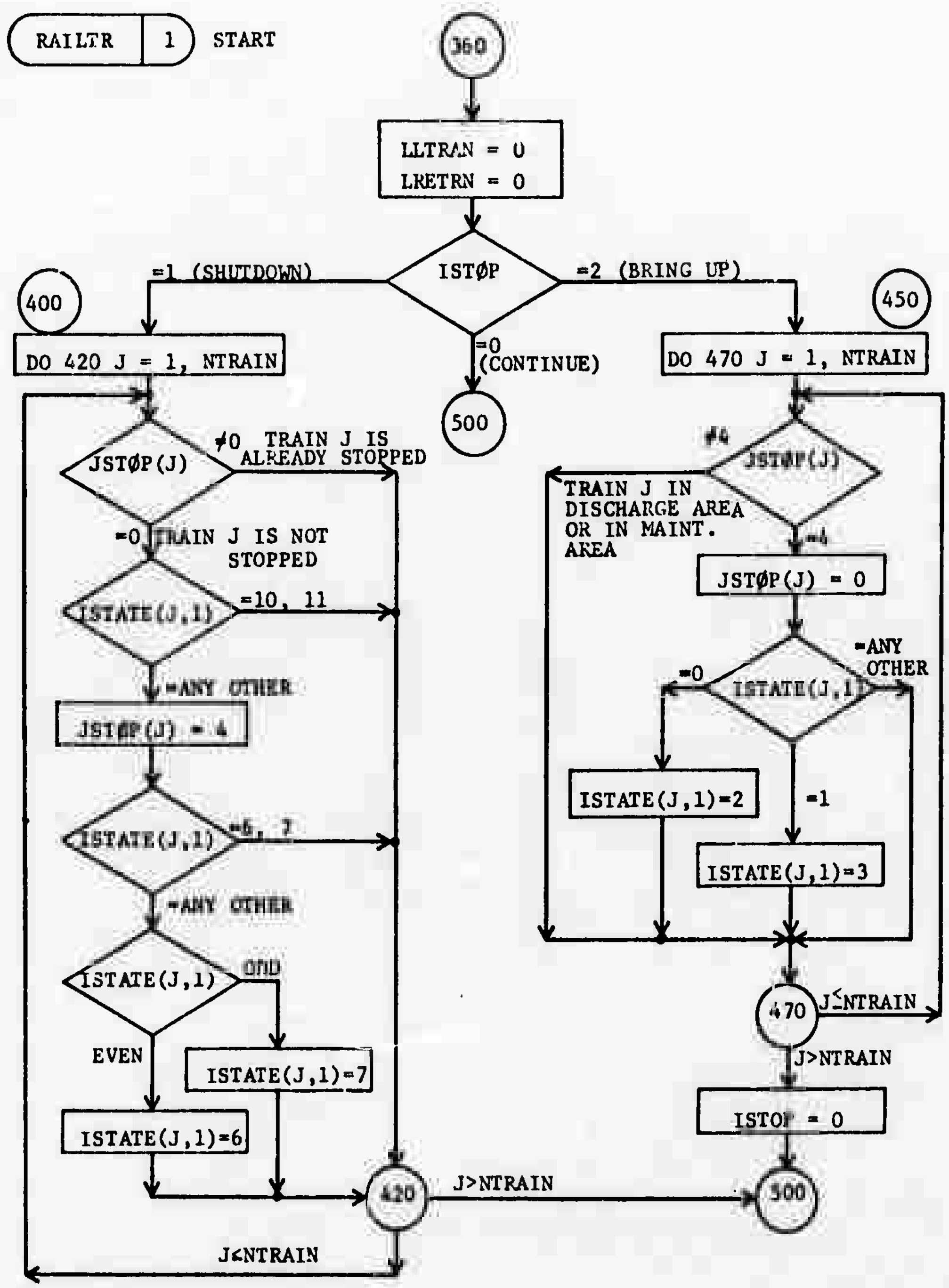
Subroutine MUKOUT



Subroutine RAILHL



Subroutine RAILHL (cont.)



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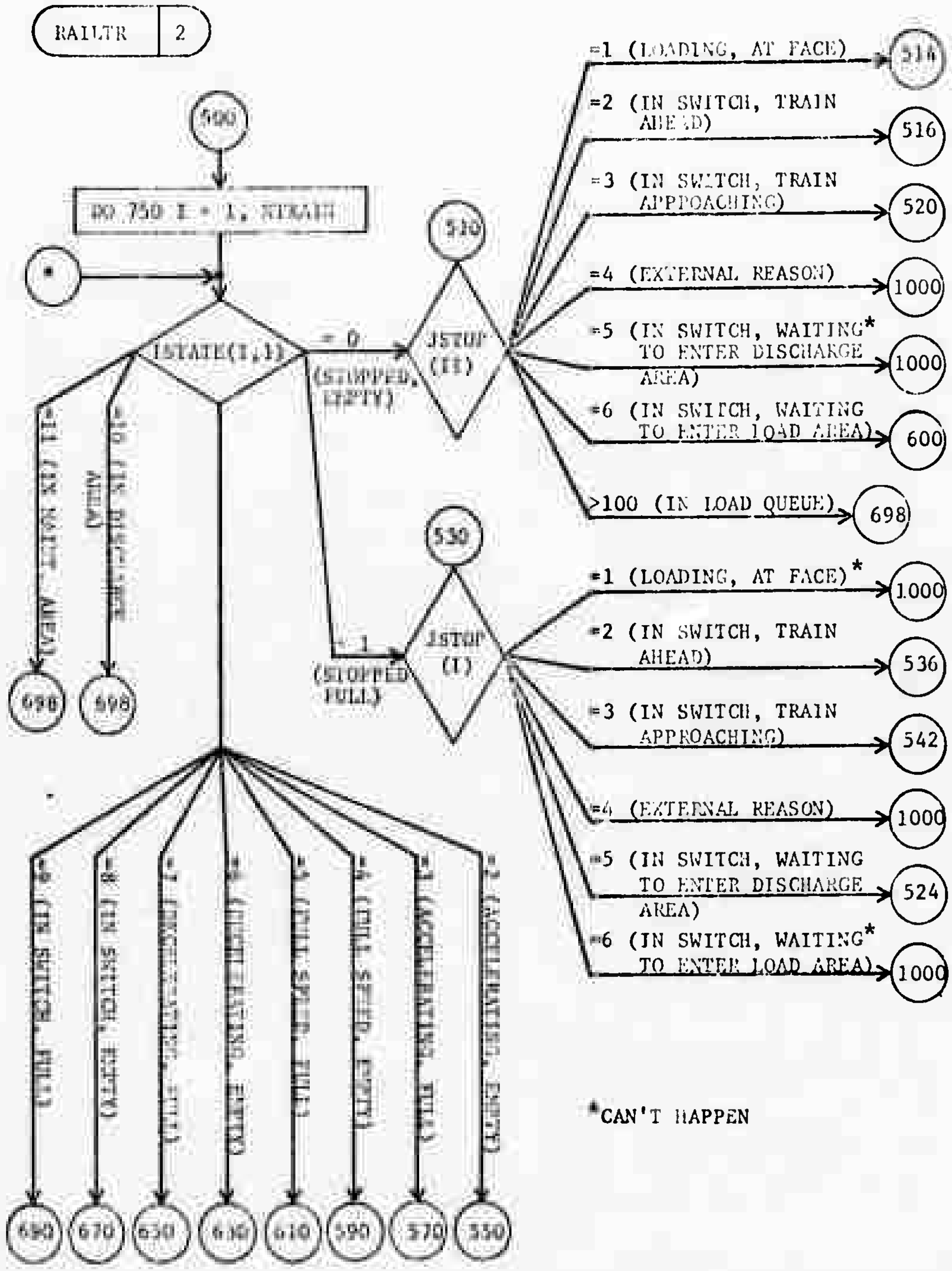
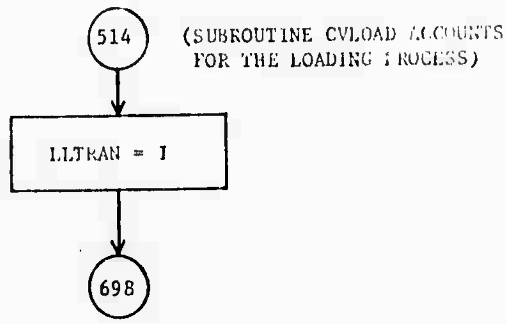


Subroutine RAILHL (cont.)

RAILTR | 3A

ISTATE(I,1) = 0
JSTOP(I) = 1

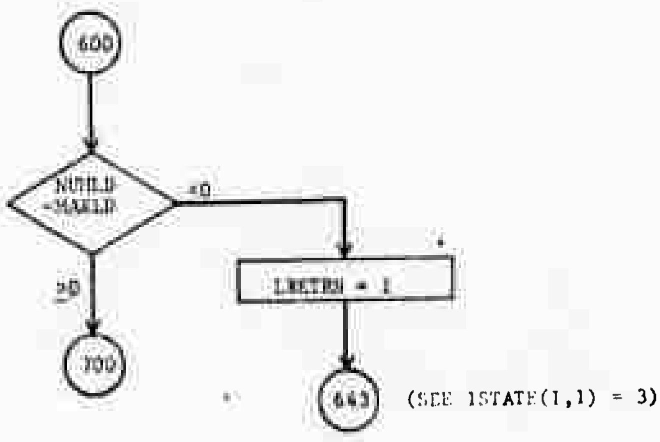
TRAIN IS STOPPED, EMPTY.
AT FACE, LOADING.



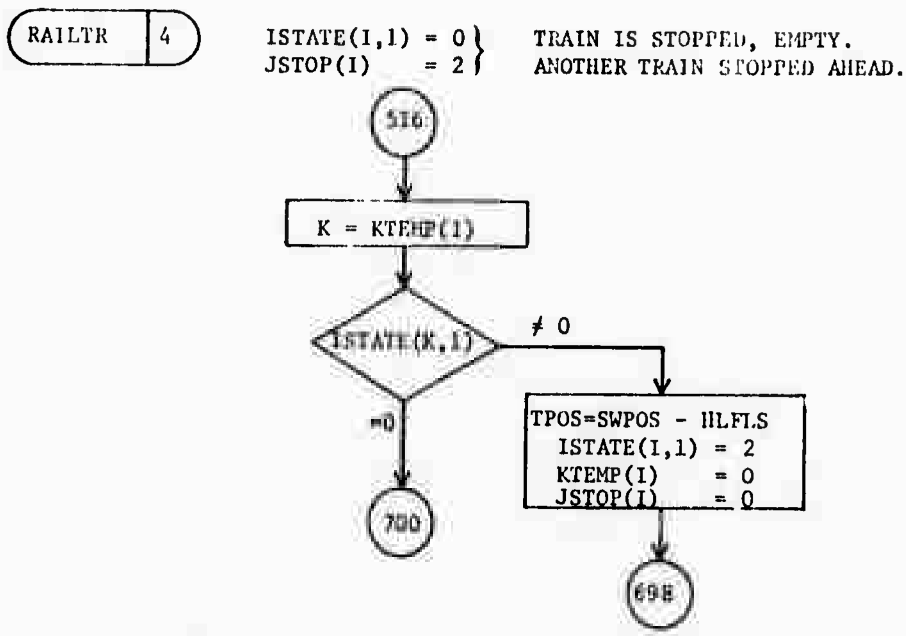
RAILTR | 3B

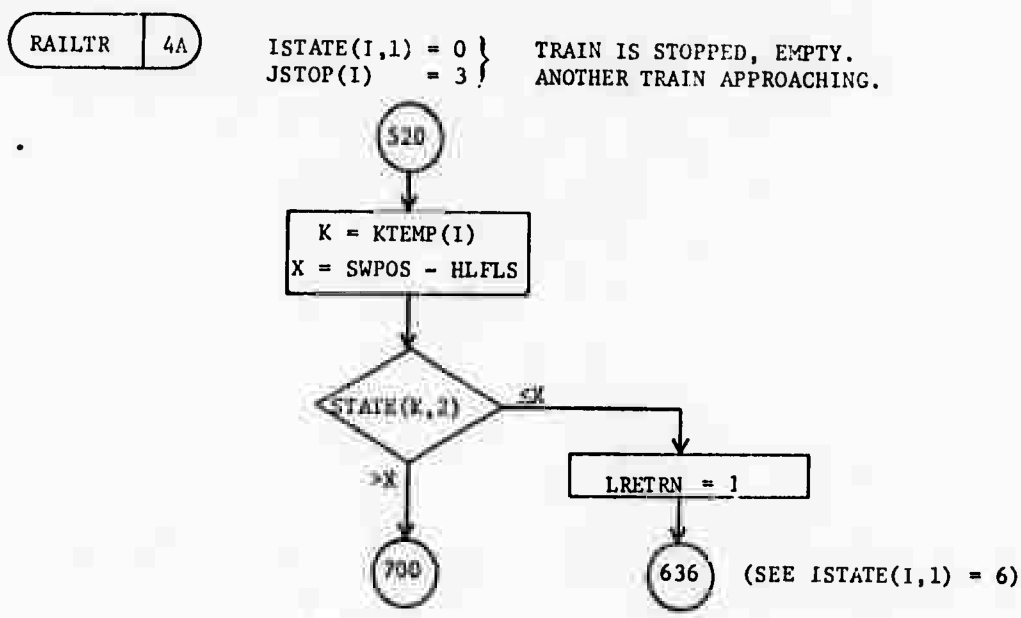
ISTATE(I,1) = 0
JSTOP(I) = 6

TRAIN IS STOPPED, EMPTY.
WAITING TO ENTER LOAD AREA.

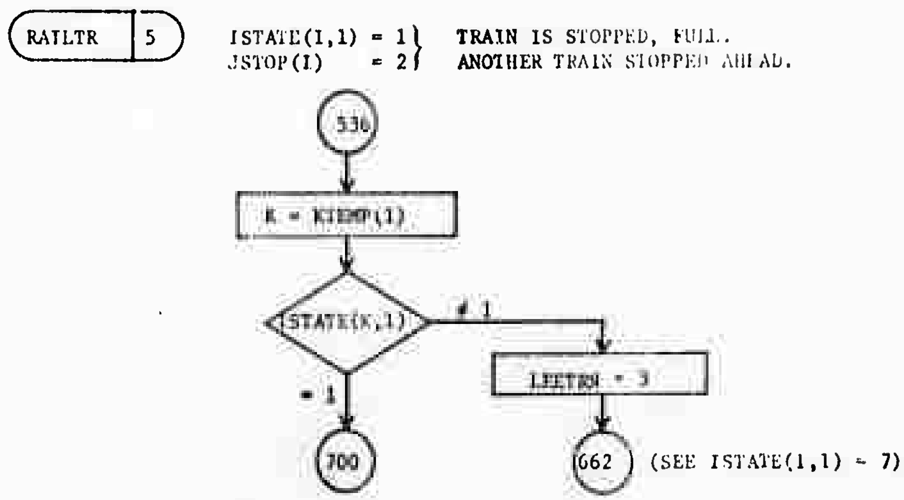


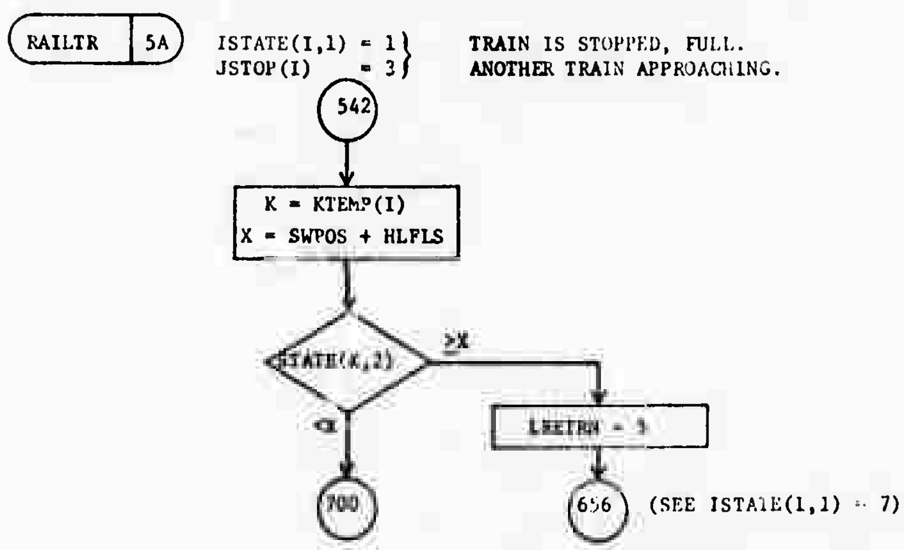
Subroutine RAILHL (cont.)





Subroutine RAILHL (cont.)



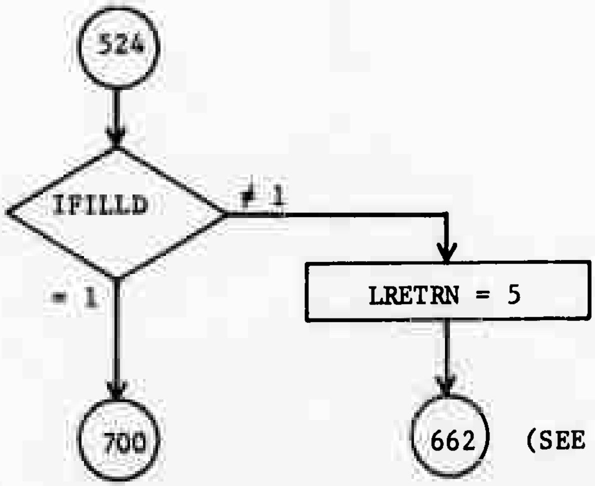


Subroutine RAILHL (cont.)

RAILTR | 6

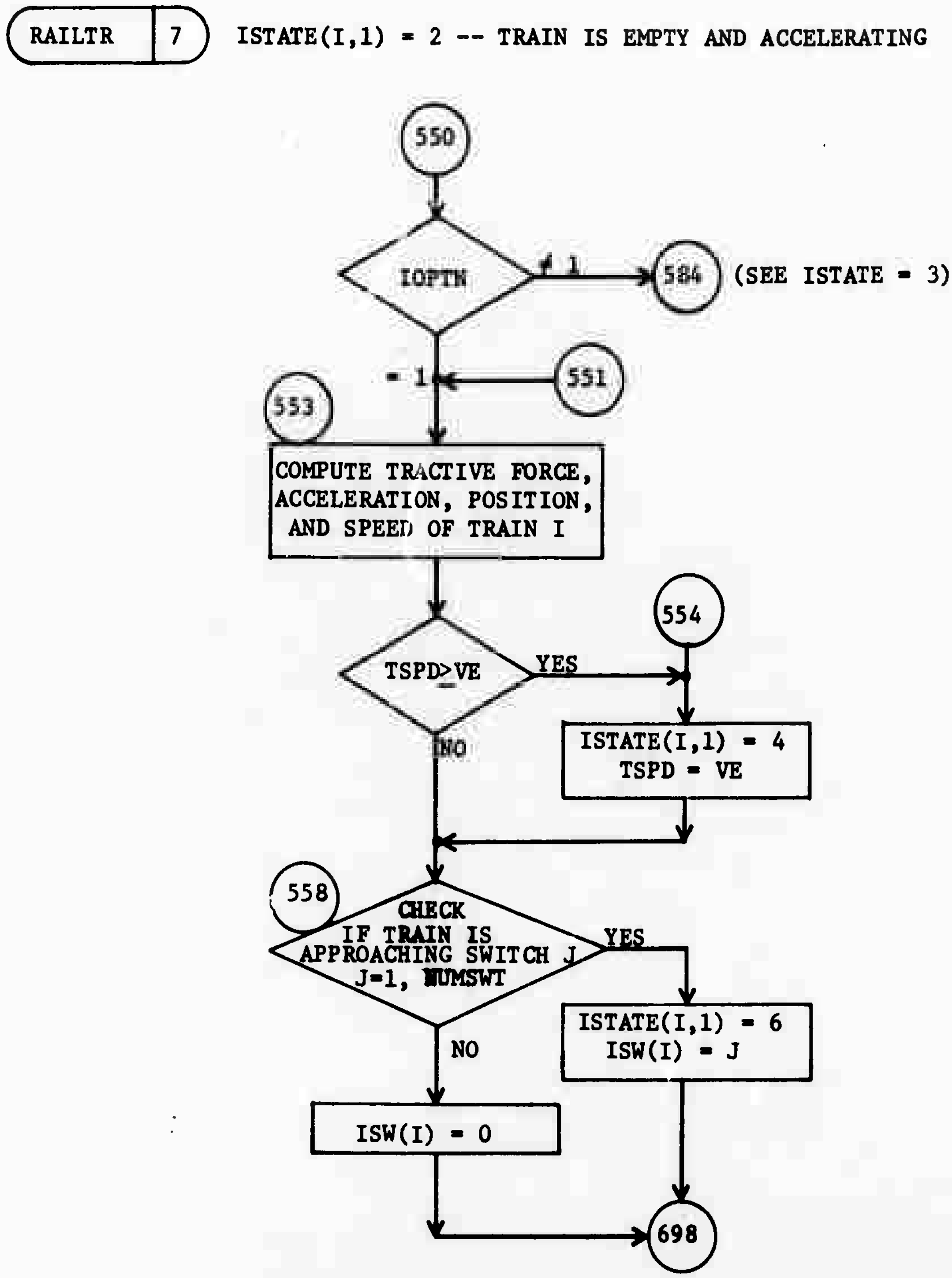
ISTATE(I,1) = 1
JSTOP(I) = 5

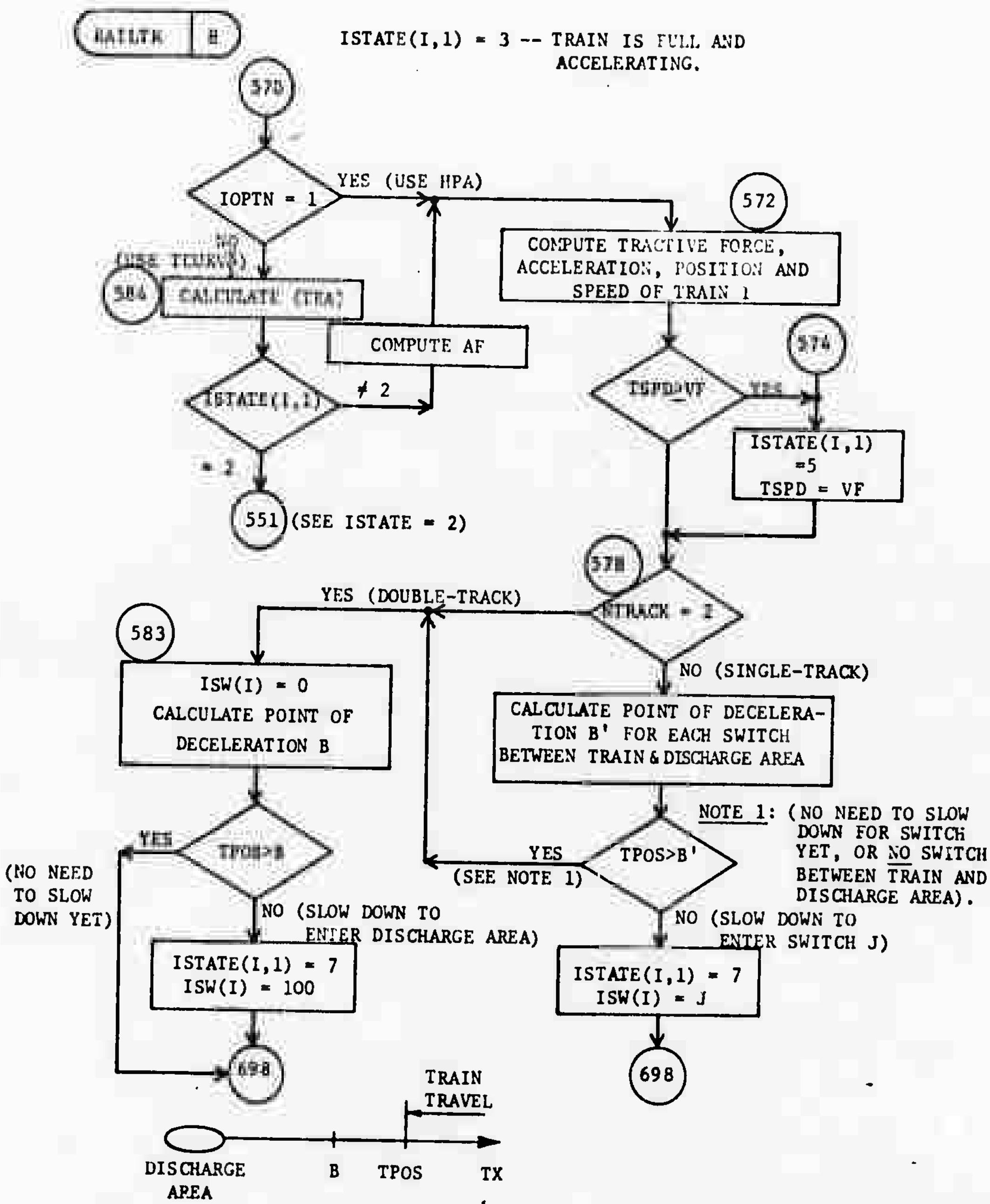
TRAIN IS STOPPED, FULL.
WAITING IN DISCHARGE AREA.



(SEE ISTATE(I,1) = 7)

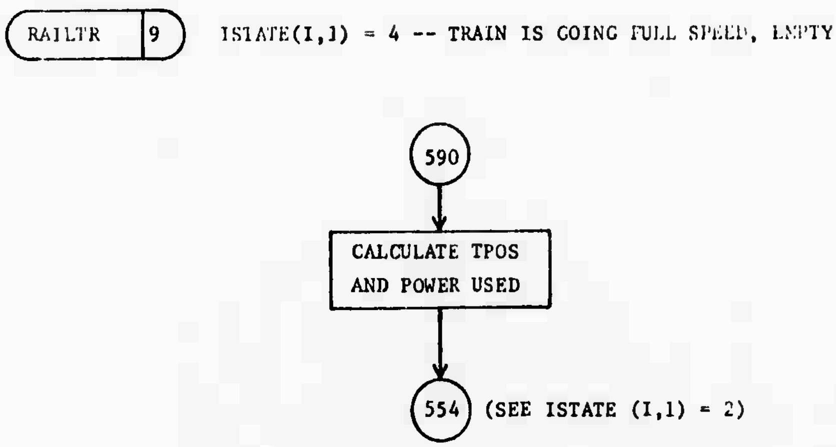
Subroutine RAILHL (cont.)

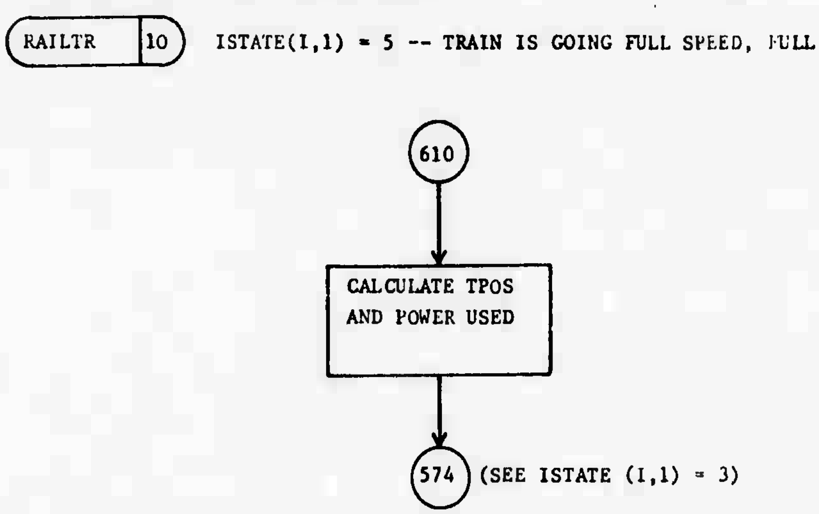




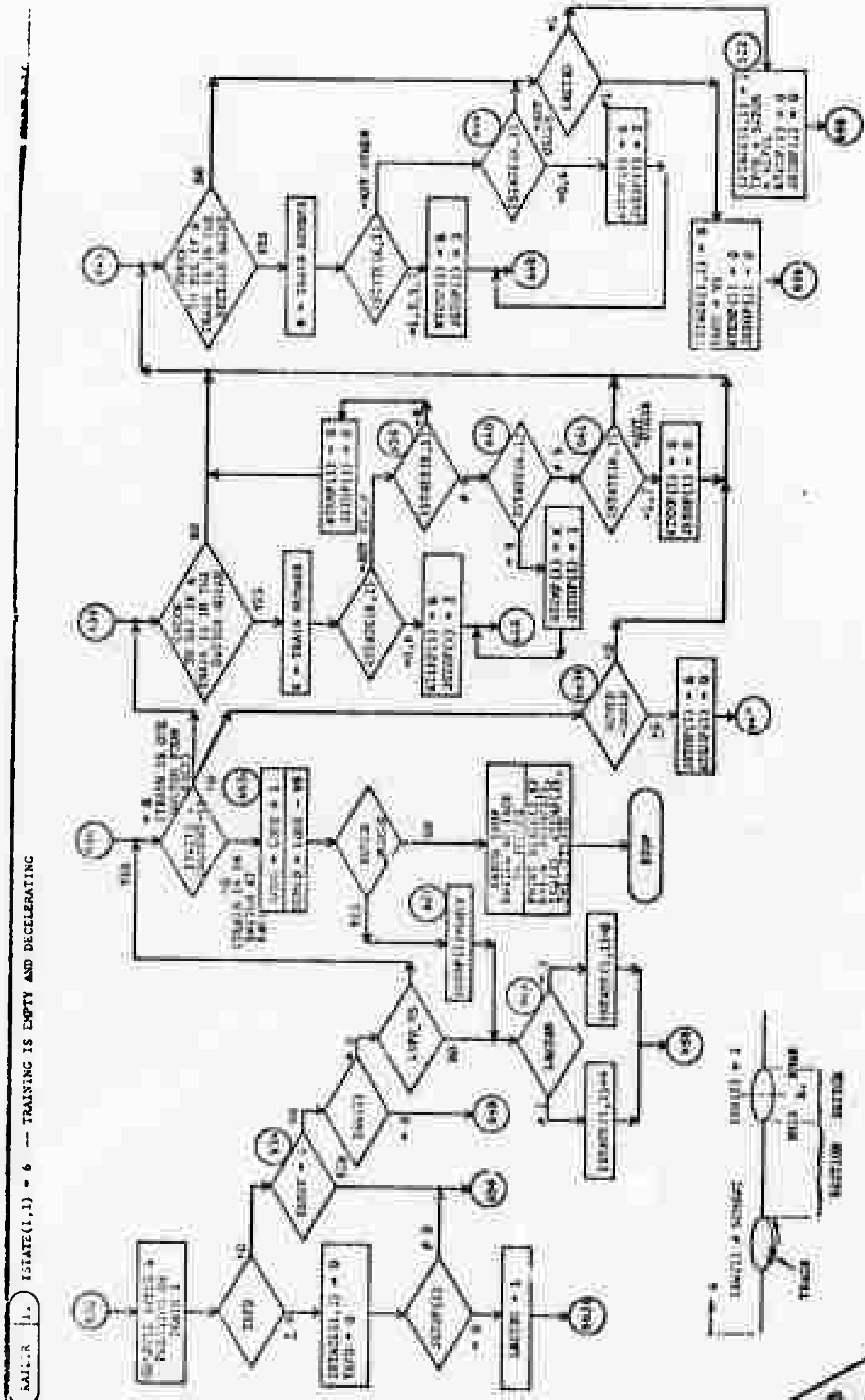
ISTATE(I,1) = 3 -- TRAIN IS FULL AND ACCELERATING.
570
IOPTN = 1
YES (USE HPA)
572
COMPUTE TRACTIVE FORCE, ACCELERATION, POSITION AND SPEED OF TRAIN I
NO
584
COMPUTE AF
ISTATE(I,1)
≠ 2
= 2
551 (SEE ISTATE = 2)
574
ISTATE(I,1) =5 TSPD = VF
YES (DOUBLE-TRACK)
583
ISW(I) = 0 CALCULATE POINT OF DECELERATION B
NO (SINGLE-TRACK)
CALCULATE POINT OF DECELERATION B' FOR EACH SWITCH BETWEEN TRAIN & DISCHARGE AREA
NOTE 1: (NO NEED TO SLOW DOWN FOR SWITCH YET, OR NO SWITCH BETWEEN TRAIN AND DISCHARGE AREA).
YES
(NO NEED TO SLOW DOWN YET)
YES
(SEE NOTE 1)
TPOS>B'
NO (SLOW DOWN TO ENTER DISCHARGE AREA)
NO (SLOW DOWN TO ENTER SWITCH J)
ISTATE(I,1) = 7 ISW(I) = 100
ISTATE(I,1) = 7 ISW(I) = J
698
698
TRAIN TRAVEL
DISCHARGE AREA
B
TPOS
TX

Subroutine RAILHL (cont.)

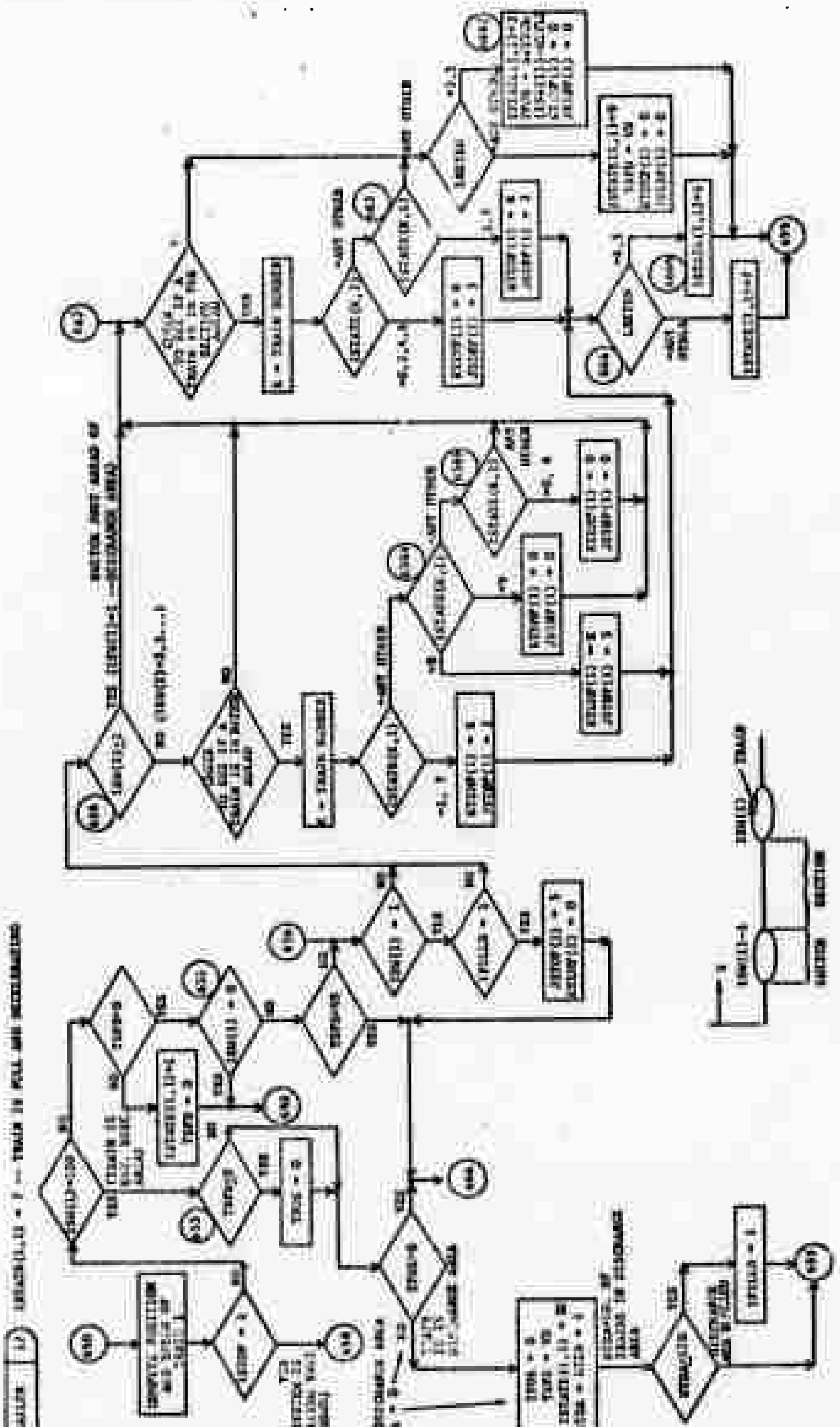




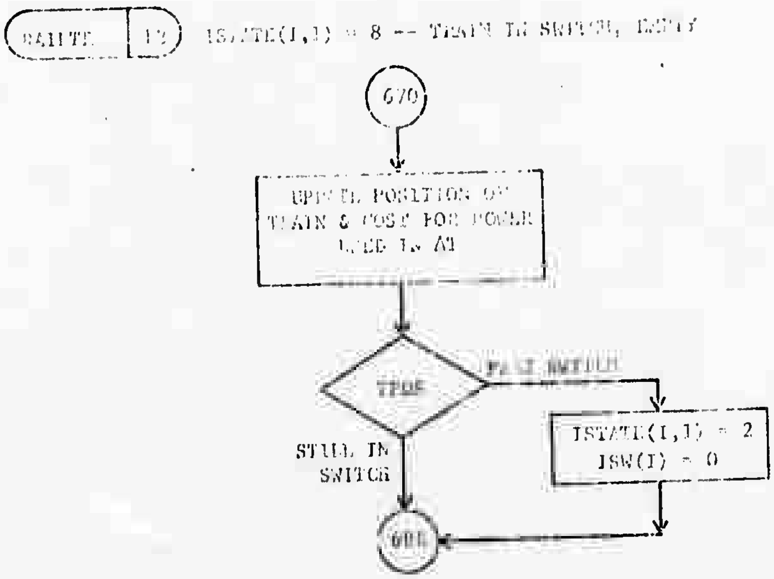
Subroutine RAILHL (cont.)

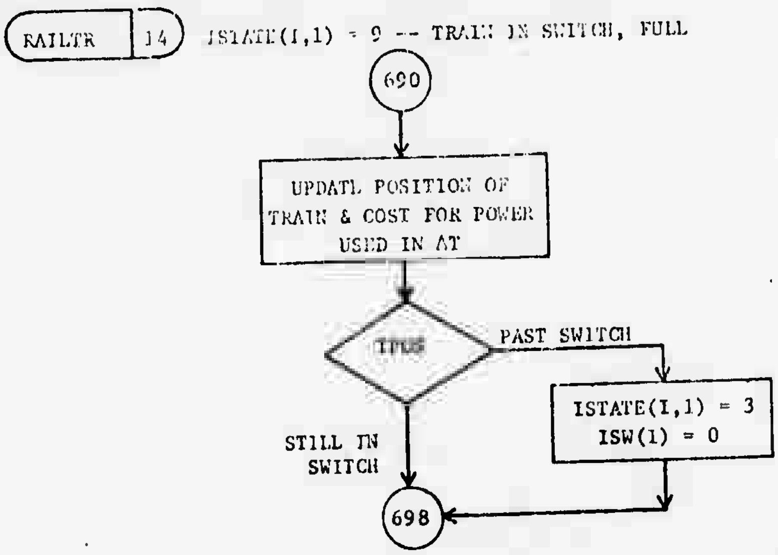


Subroutine RAILHL (Cont.)

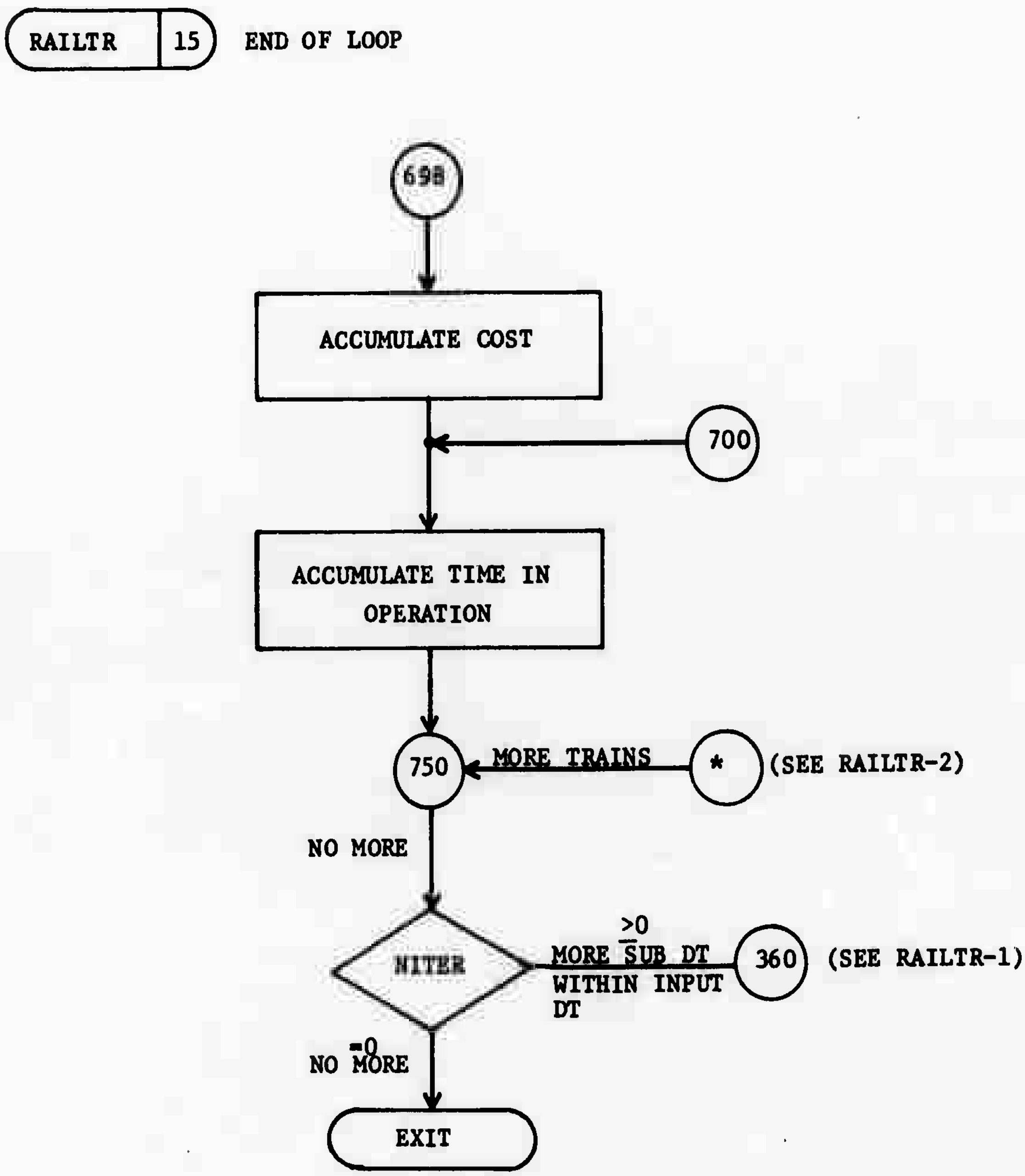


Subroutine RAILHL (cont.)

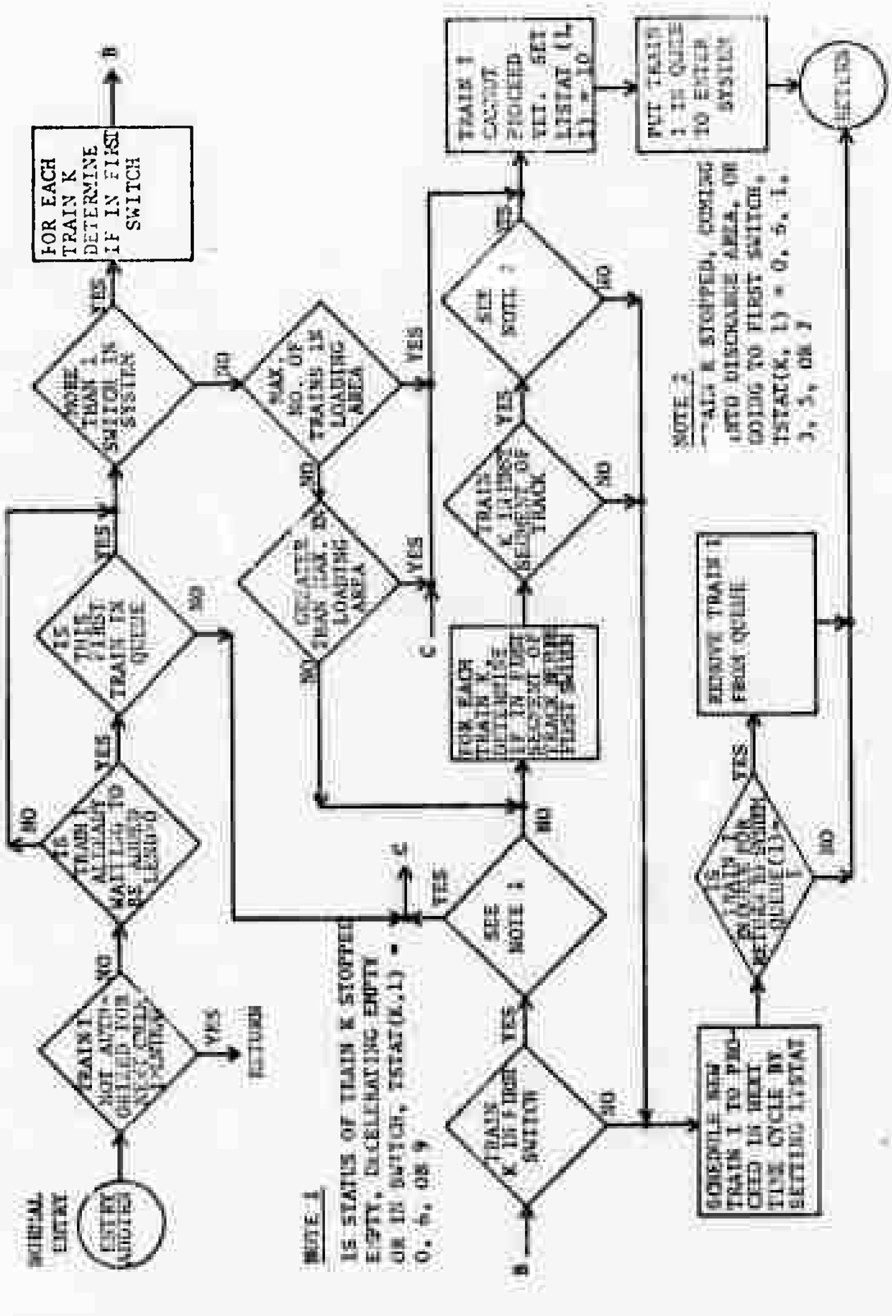




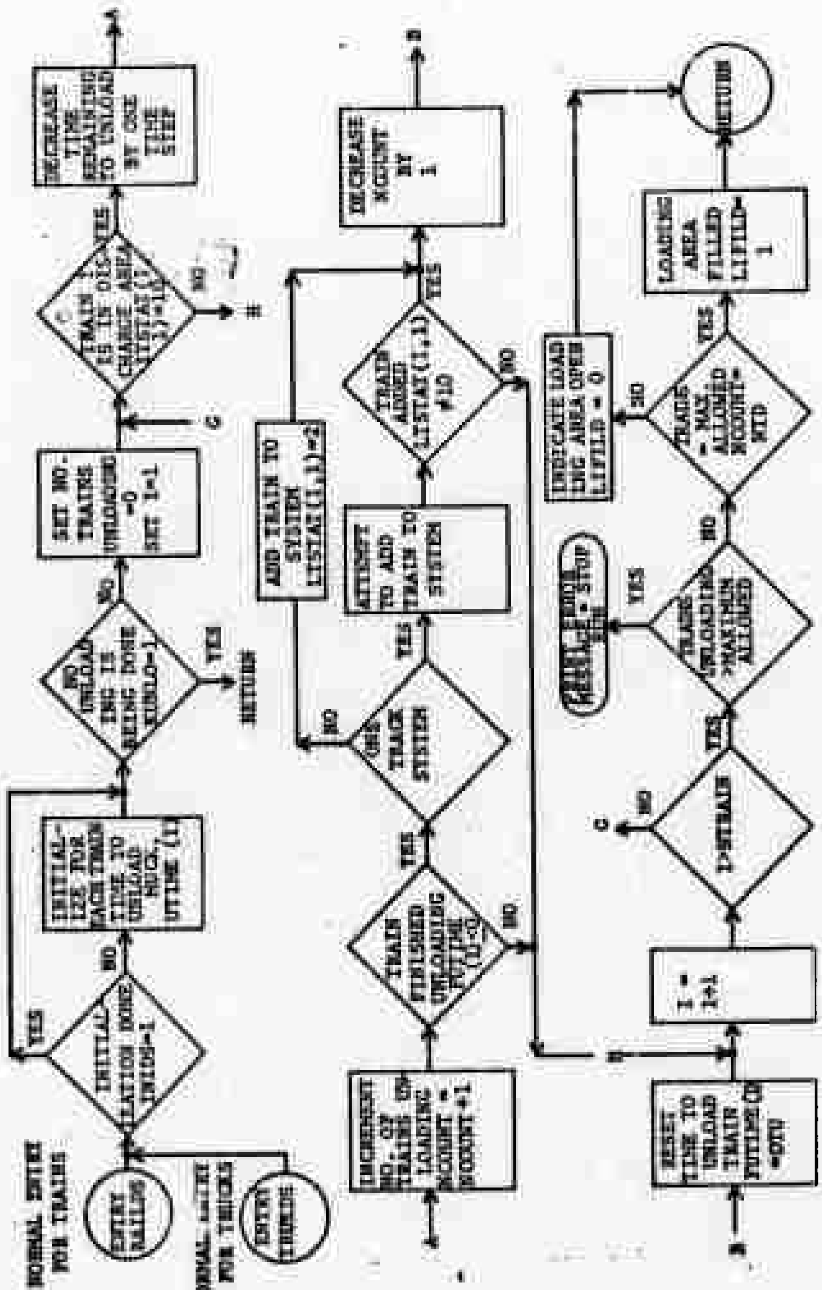
Subroutine RAILHL (cont.)



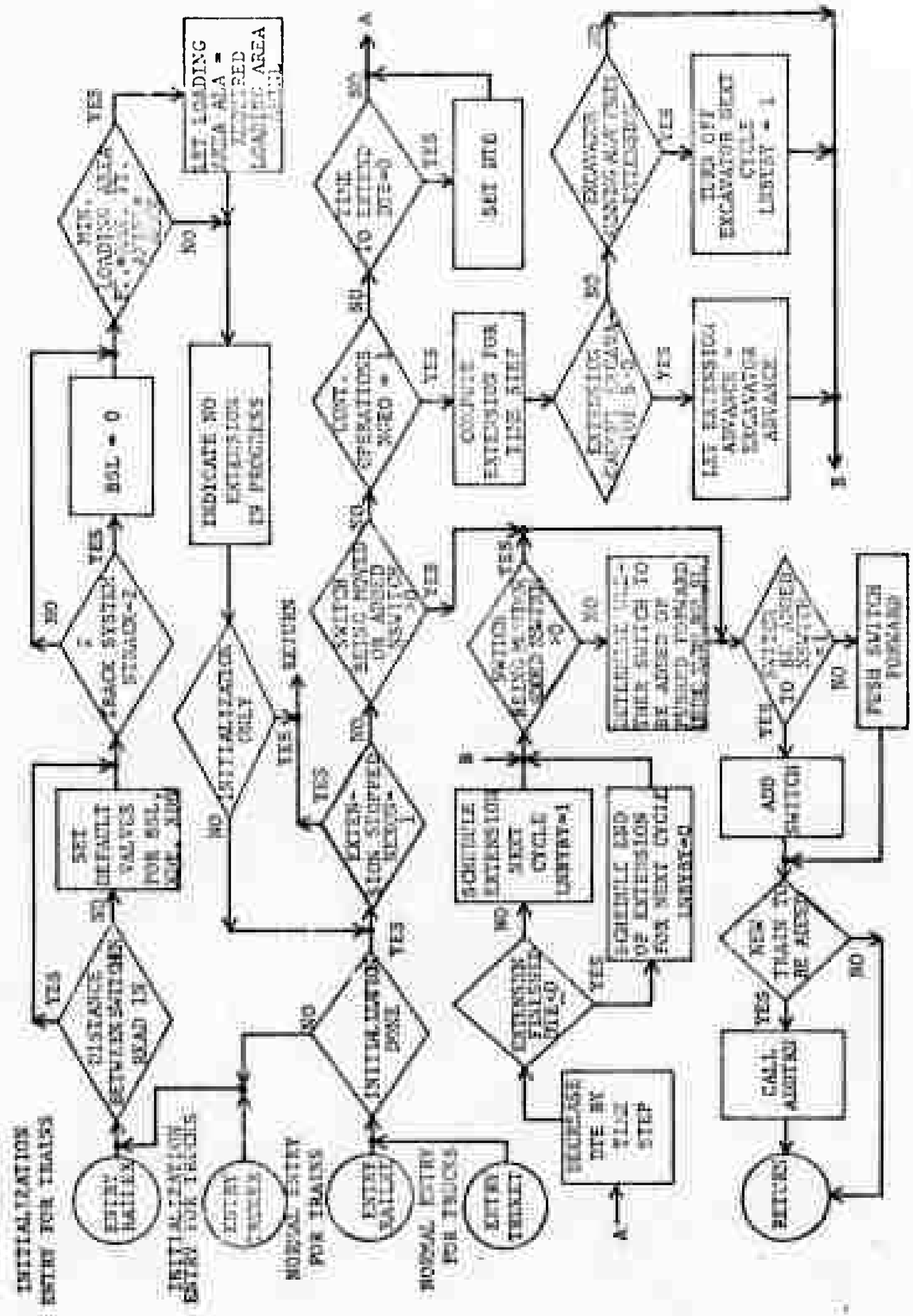
Subroutine ADDTRN



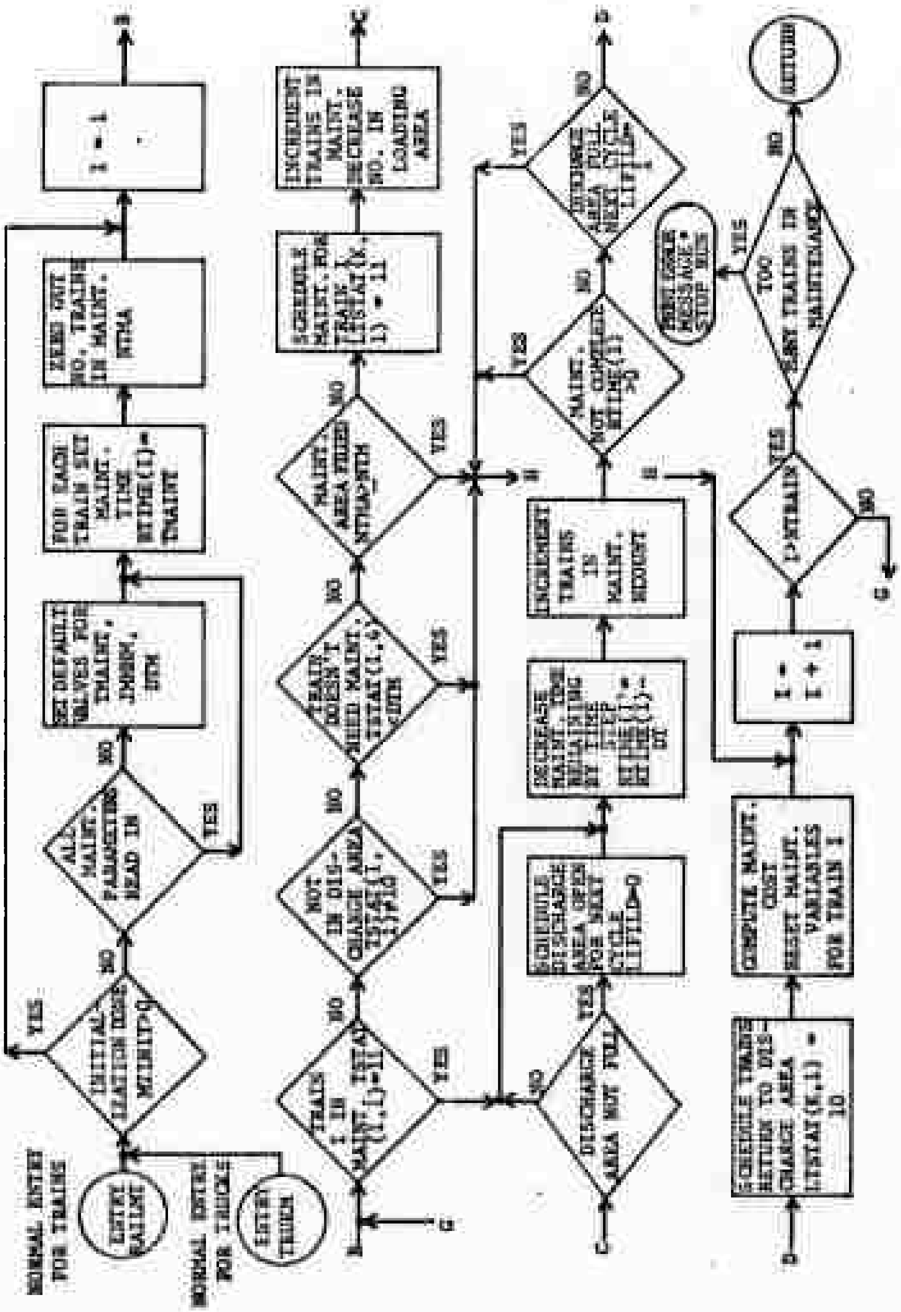
Subroutine RAILDS



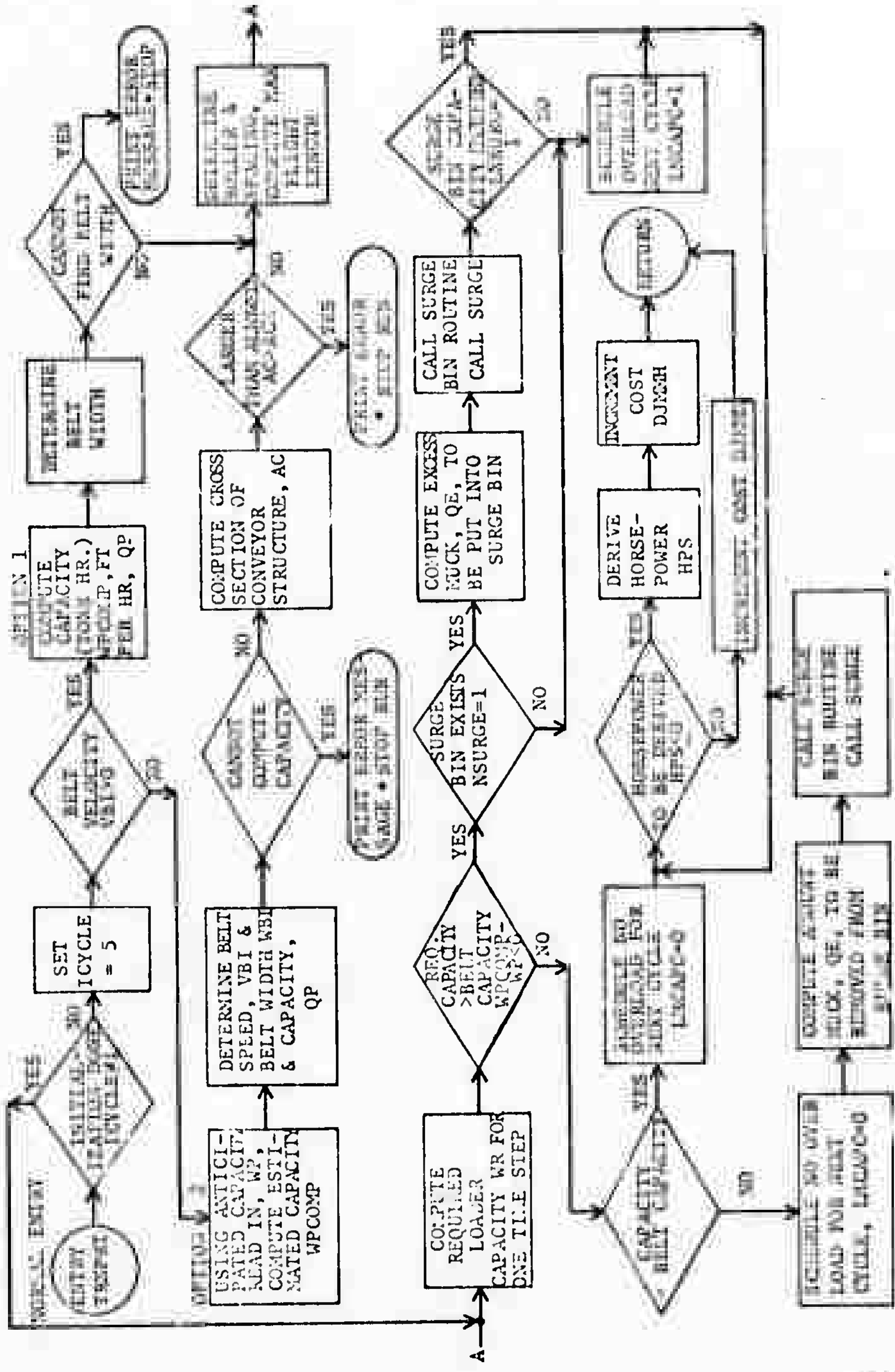
Subroutine RAILEX



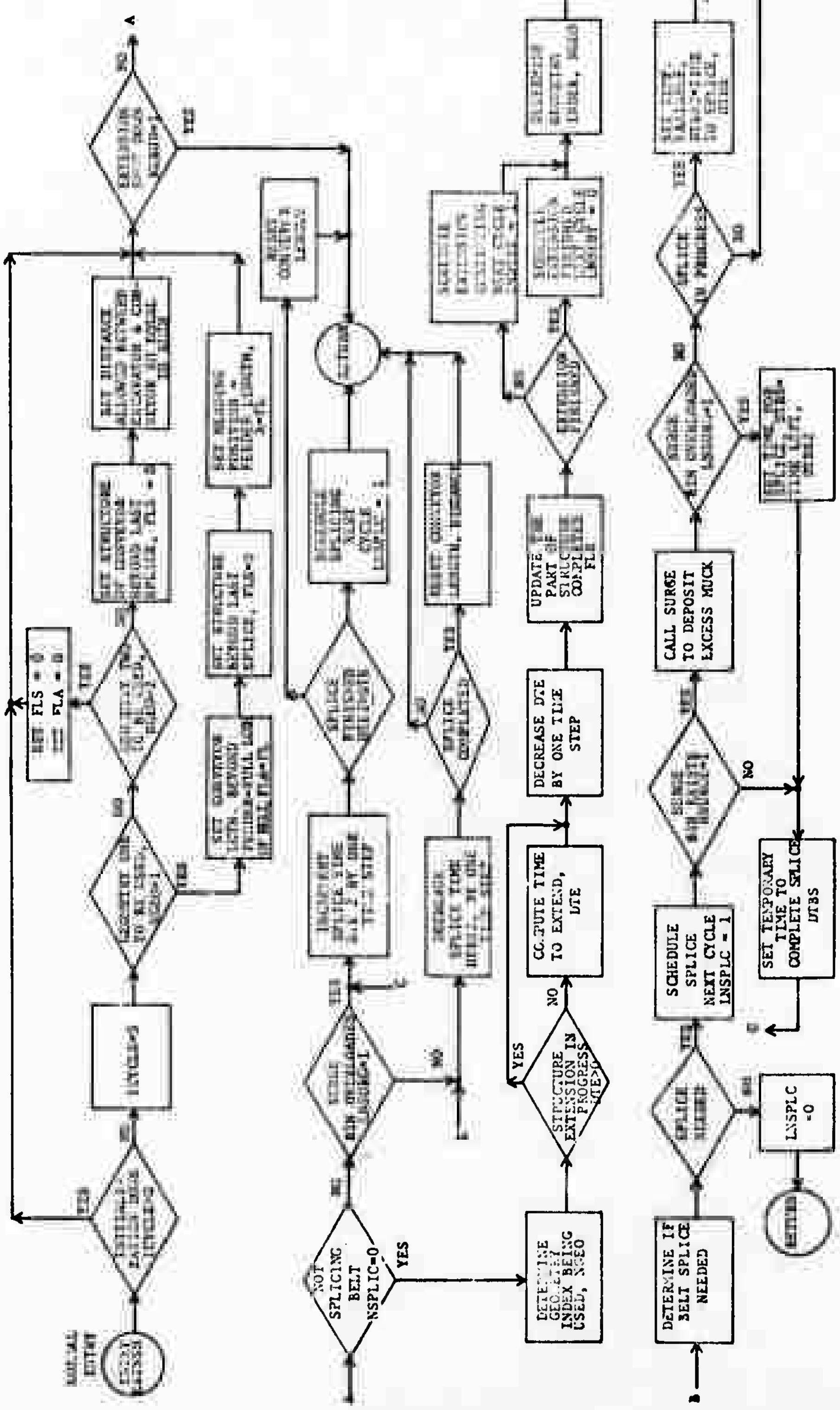
Subroutine RAILMT



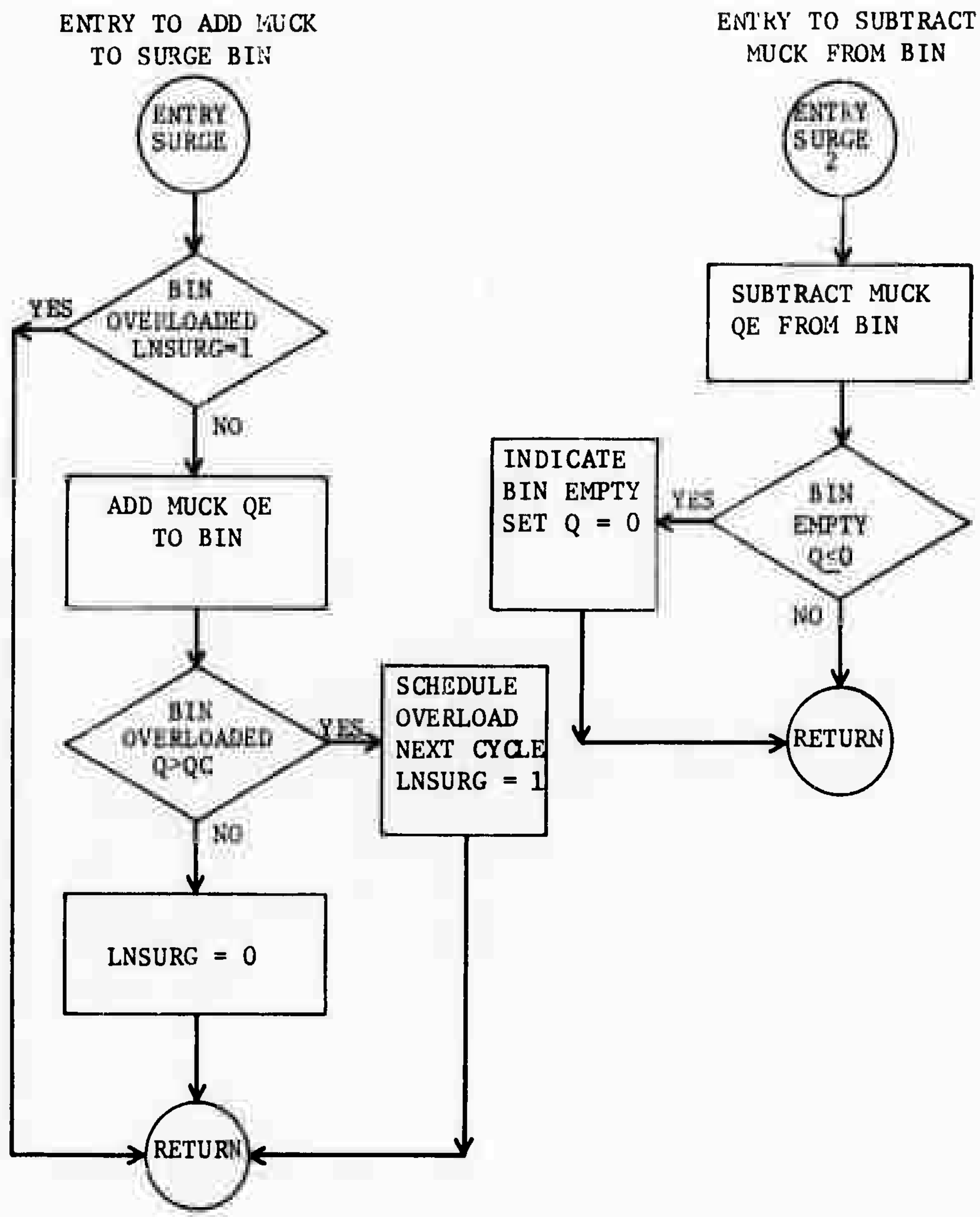
Subroutine TRNPRT



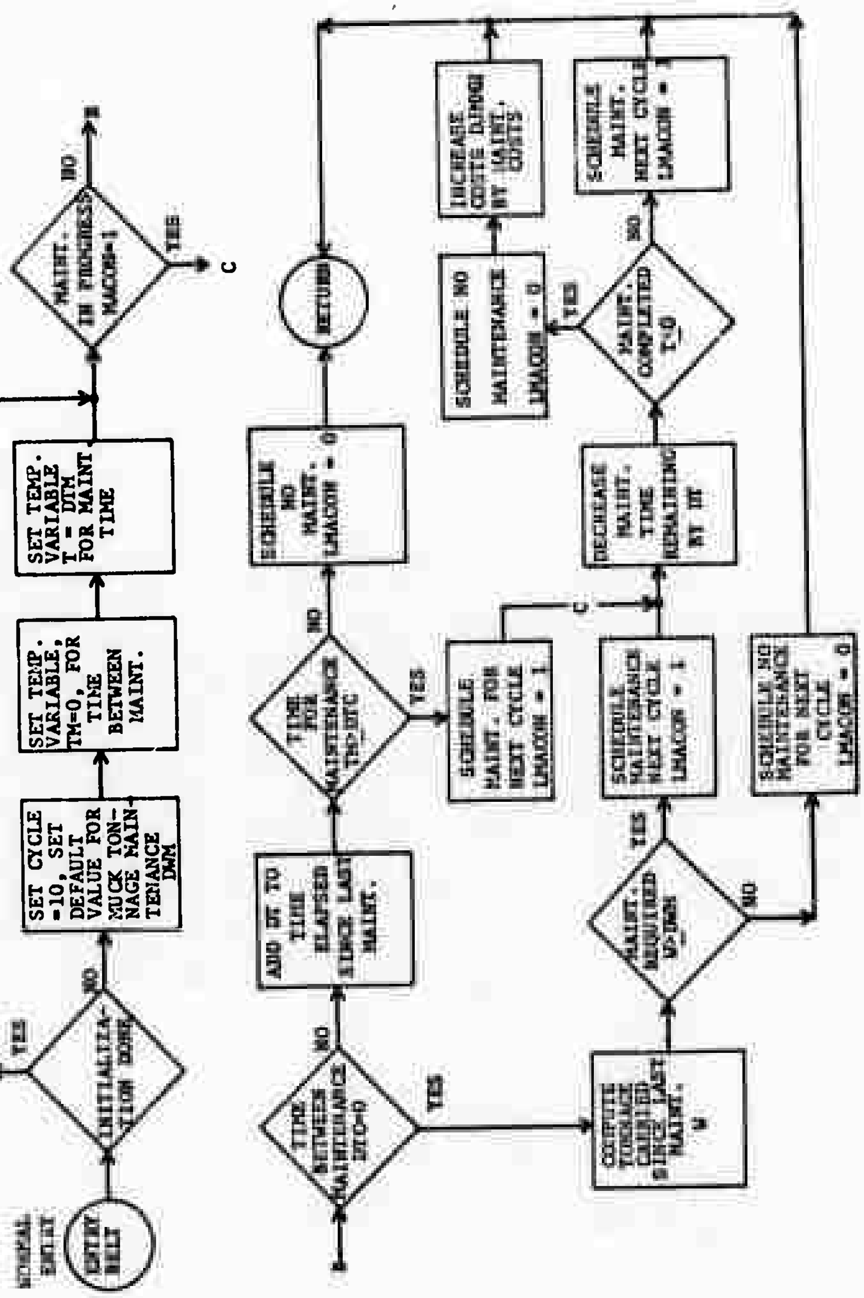
Subroutine EXTNSN



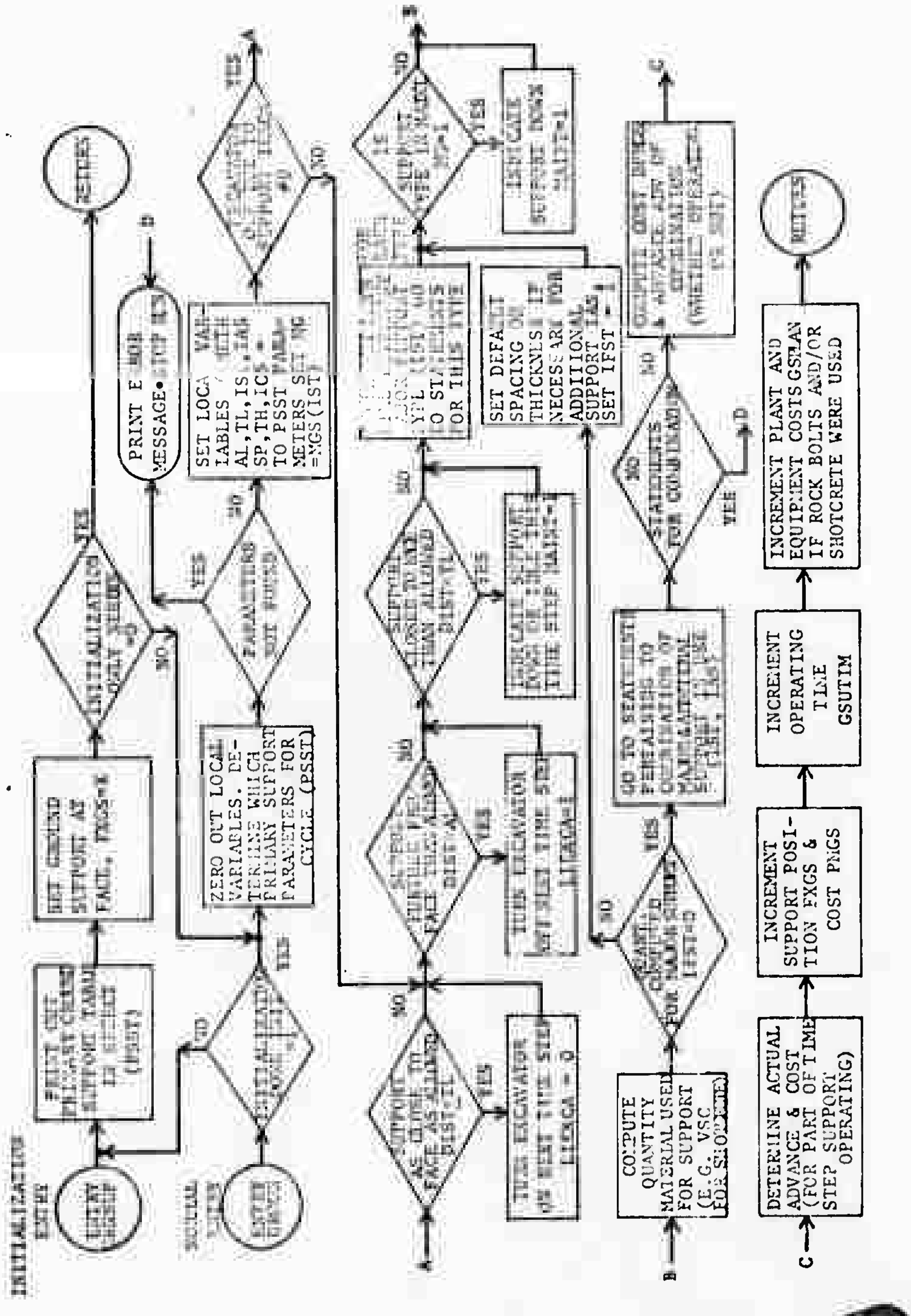
Subroutine SURGE



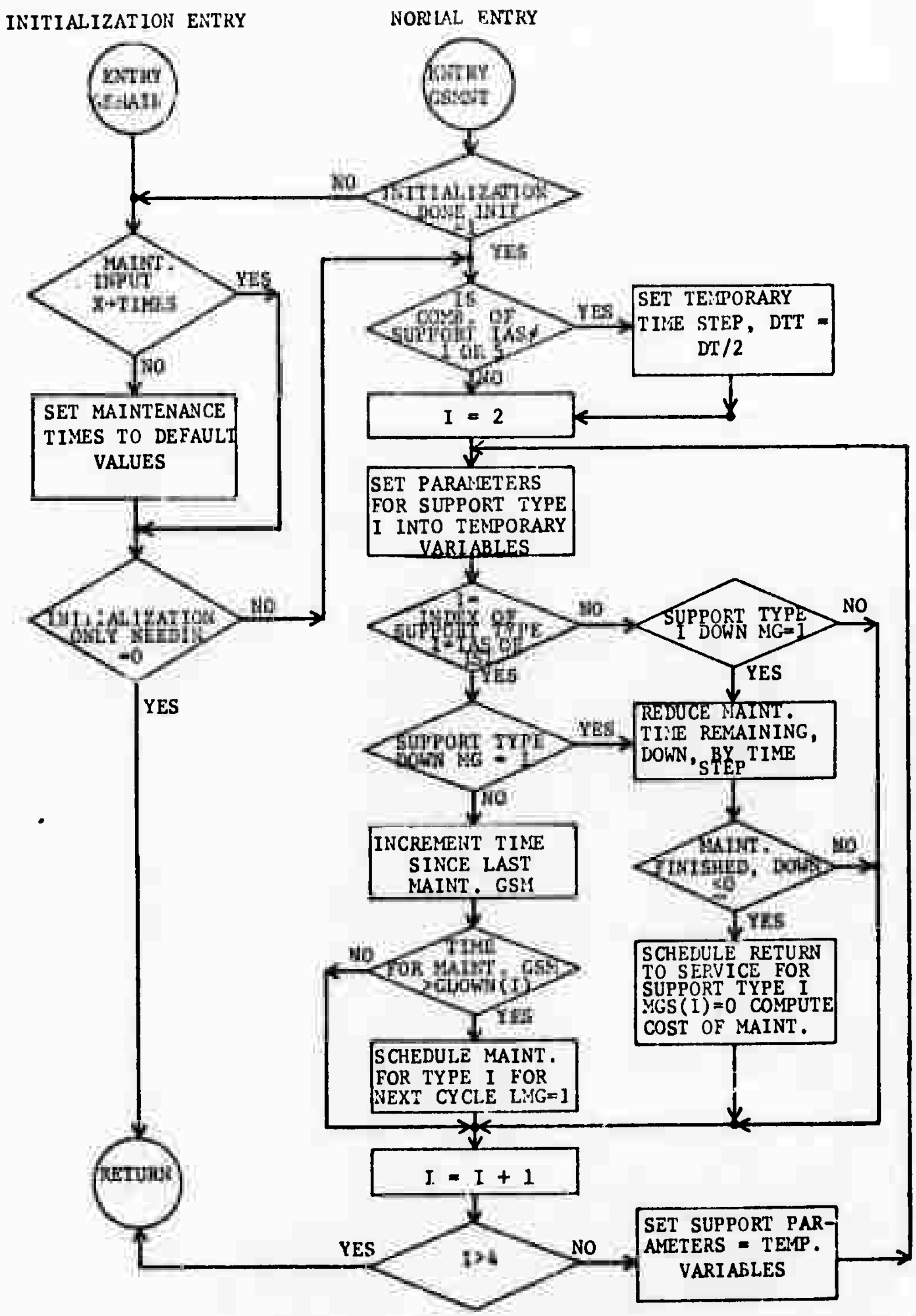
Subroutine BELT



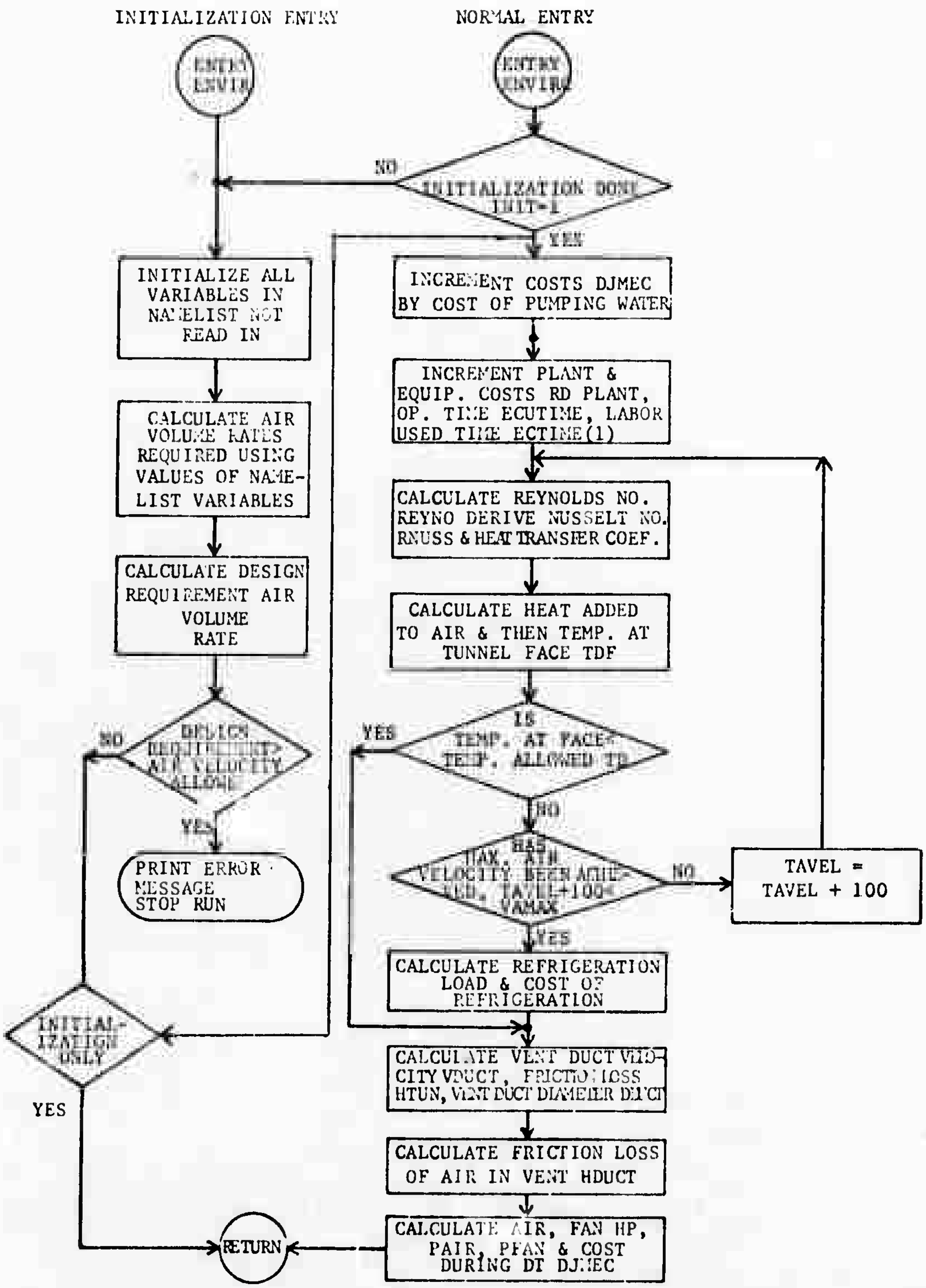
Subroutine GRNSUP



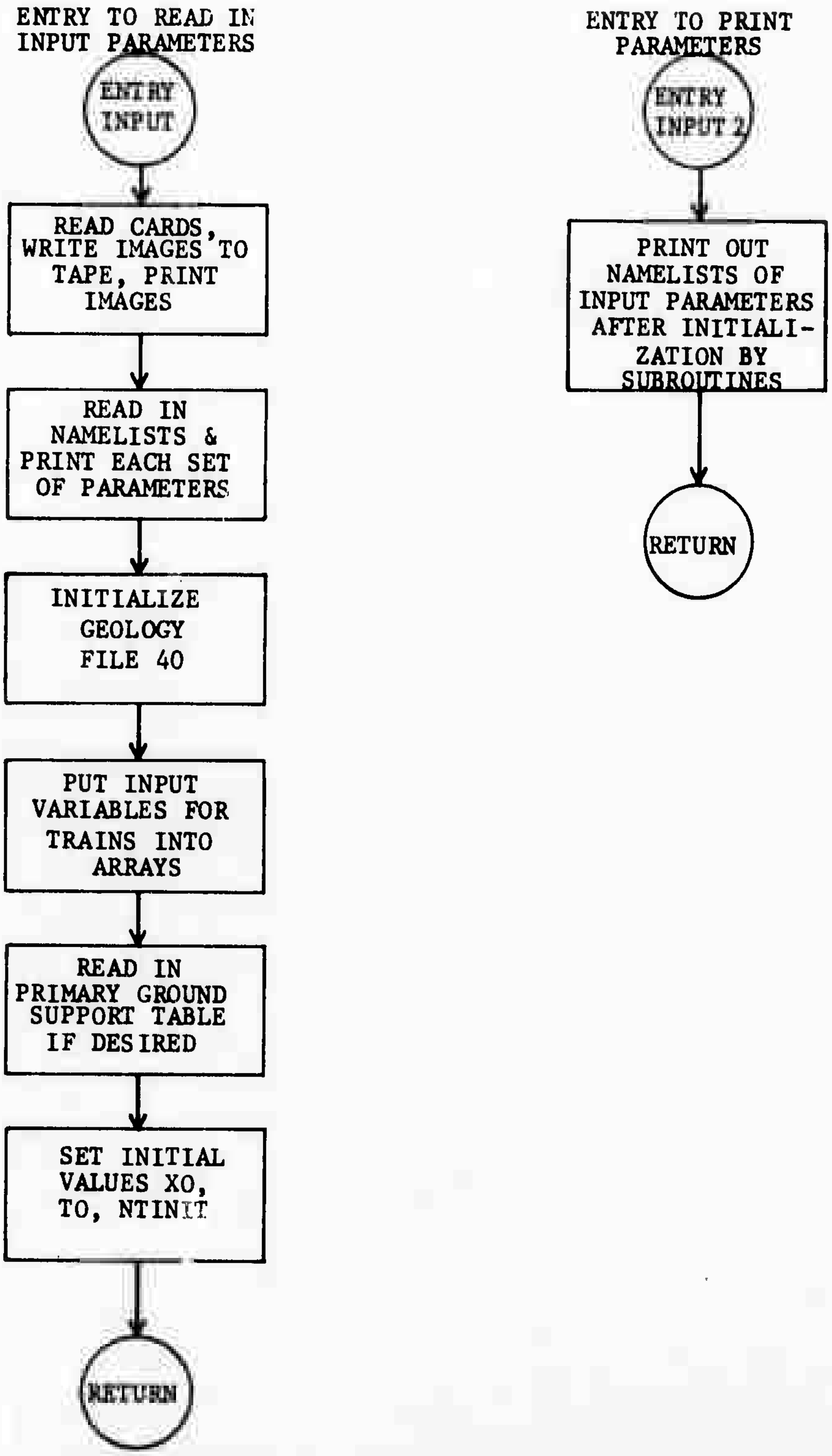
Subroutine GSMAIN



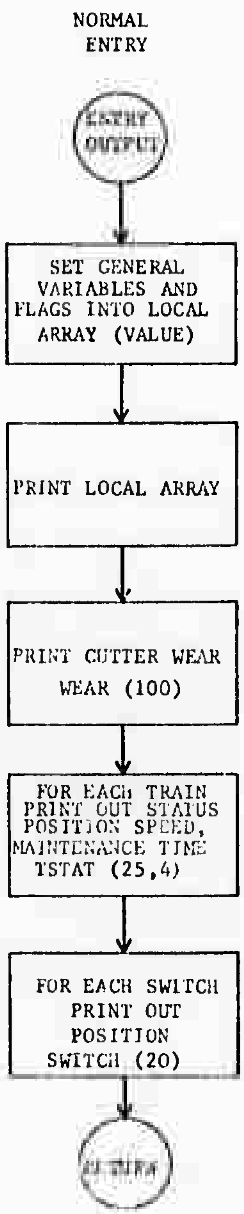
Subroutine ENVIR



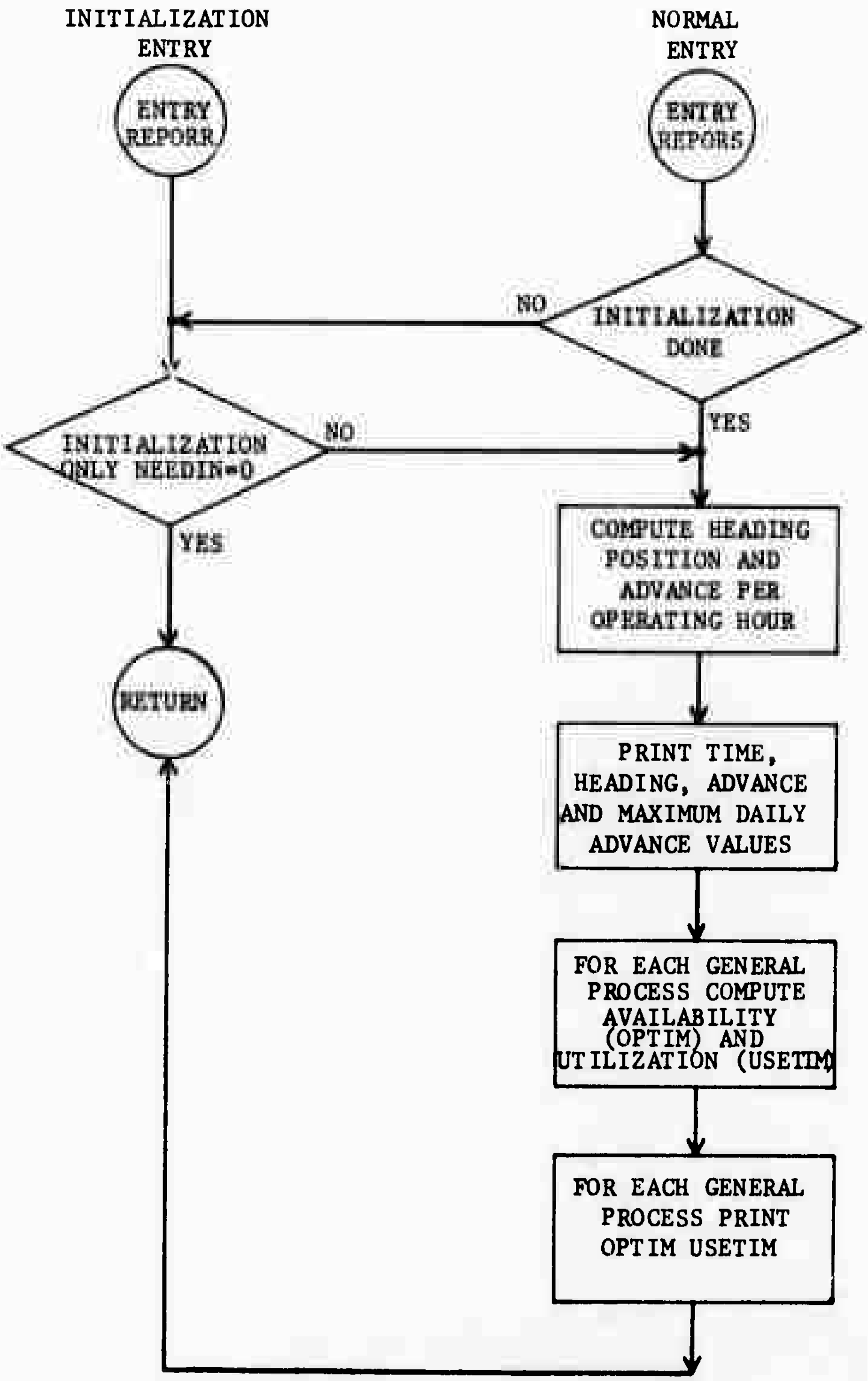
Subroutine INPUT



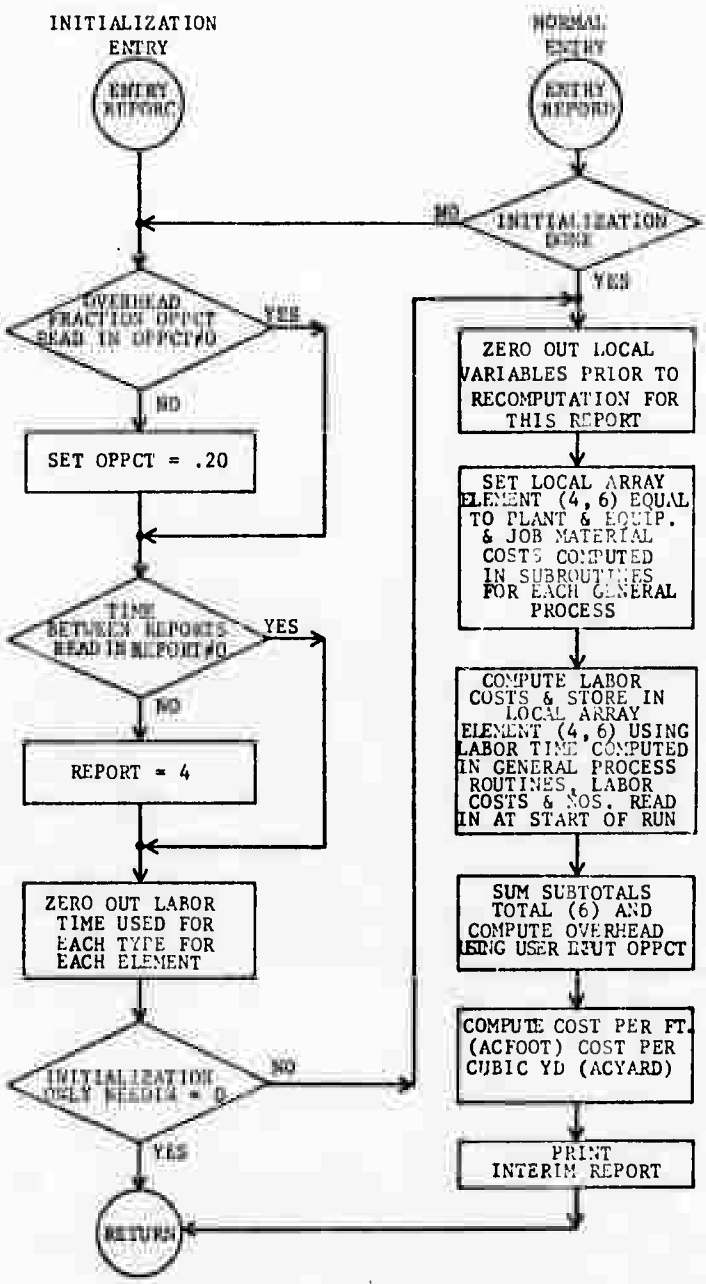
Subroutine OUTPUT



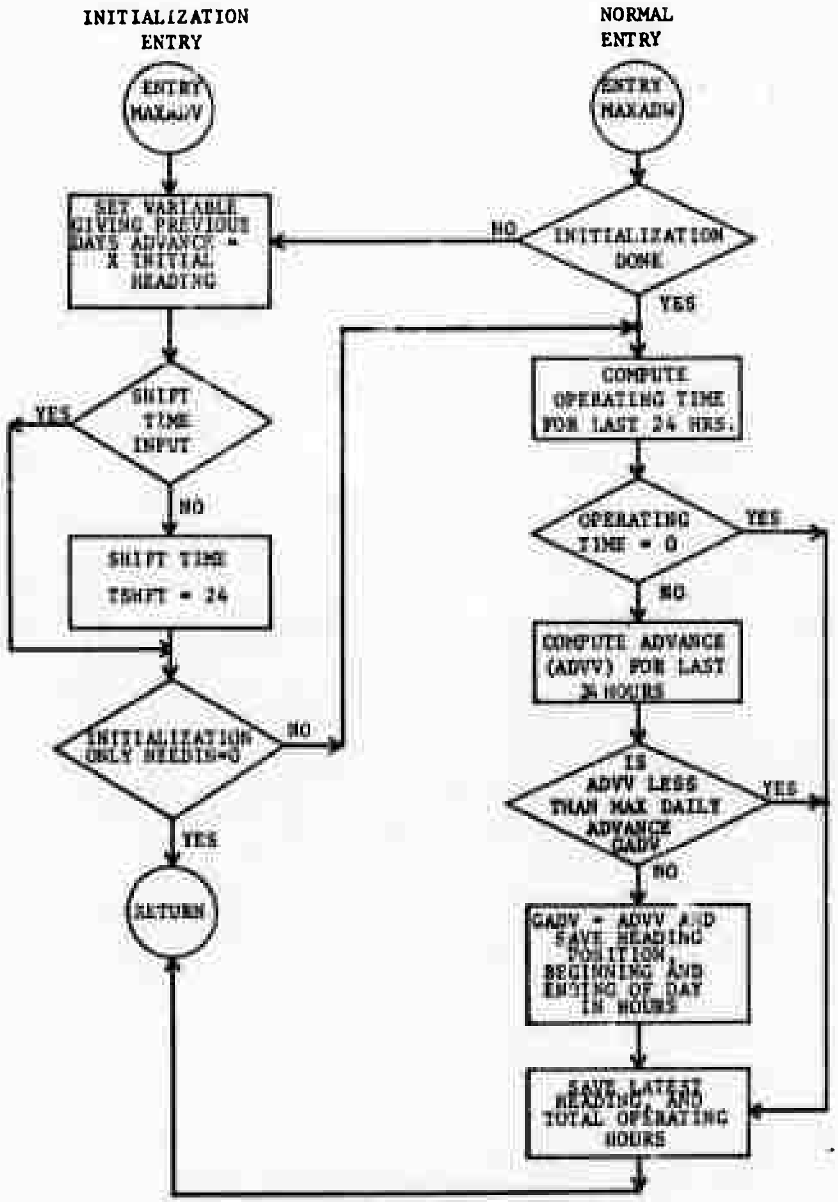
Subroutine REPORR



Subroutine REPORC



Subroutine MAXADV



III. NOTES ON INCORPORATING SUBROUTINES INTO A CONTROL PROGRAM

In writing a control program to incorporate any routines described in Sec. II which are not now in the sample control program, several things must be kept in mind.

A. Status variables which exist in a new and old form must be placed in NEWCOM and OLDCOM.

B. Common blocks which are needed but not at present in the routines' decks must be put into the decks. Also any common block in any routine must be put into the control program.

C. The NAMELIST which is to read in the input variables for the routines must be put into INPUT if the INPUT routine is going to be used to initialize. Both the definition of the NAMELIST and the calls to read it, write it on tape, and print it must be in INPUT.

D. OUTPUT must be changed to print the common variables associated with the processes being simulated.

E. Job material costs computations are already in the routine sets. However, computations for labor costs, plant and equipment costs, and utilization values are not in the suoroutines. Procedure to add these three is as follows:

1. Labor costs - add the following to the NAMELIST which is associated with routine set:

   a. Number of men needed in each of 1 to 10 labor categories

   b. Hourly cost of one man in each category

   The variables representing these parameters are dependent on the element the set simulates:

   <u>Rock Fragmentation</u>

   a. BOMEN(10) b. BOCST(10)

Materials Handling (Short Haul)

a. RAMEN(10) b. RACST(10)

Ground Support

a. GMEN(10) b. GCST(10)

Environmental Control

a. VCMEN(10) b. VCCST(10)

Next, in one routine of the set accumulate labor time used for each time cycle by one of the following statements depending again upon the element being simulated by the routine set.

a. Rock disintegration
RDTIME = RDTIME + DT

b. Materials handling (short haul)
HTIME(2) = HTIME(2) + DT

c. Materials handling (long haul)
HTIME(1) = HTIME(1) + DT

d. Ground support
GSTIME = GSTIME + DT

e. Environmental control
ECTIME = ECTIME + DT

These may be bypassed by checking status variables as desired, so labor costs are not always incremented. The computation of cumulative labor costs is then done in the report routines.

2. Plant and equipment costs - first add to the routine set's NAMELIST and common block, variables for costs for plant various types of plant and equipment. Each cost should be either hourly cost or cost per foot.

Next add a statement to one routine in the set which computes the cost for either a time step (DT) or for a foot advance (DX) and cumulates the cost in one of the following variables depending on the element being simulated:

a. Rock disintegration
   RDPLAN

b. Materials handling (long or short haul)
   HPLANT

c. Ground support
   GSPLAN

d. Environmental control
   ECPLAN

Again, as with labor costs, the computing of cost in any time step can be bypassed by a check of status variables.

3. Utilization times:
   To determine utilization values, it is necessary to compute operating time and down time. Then knowing shift time, the utilization of each element can be computed in the report subroutines according to the formulas:

$$\text{Availability} = \frac{\text{Shift time - down time}}{\text{Shift Time}}$$

$$\text{Utilization} = \frac{\text{Operating time}}{\text{Shift time}}$$

Operating time and down time must be cumulated in each time cycle. Status variables should be used to determine which, if either, should be added to in each time cycle. The cumulating is done in routines of the set for each process being simulated. The variables used for cumulating the time are:

	Operating Time	Down Time
Rock Fragmentation	RDUTIM	RDDTIM
Materials Handling (long & short haul)	UMHTIM	DMHTIM
Ground Support	GSUTIM	GSDTIM
Environmental Control	ECUTIM	ECDTIM

NOTE: Since there are two sets of routines for materials handling, care must be taken in computing the operating time for materials handling as a whole to avoid double counting.

IV. GENERAL REQUIREMENTS FOR THE CONTROL PROGRAM LOGIC

Figure IV-4 represents the logic for a control program to coordinate the tunneling processes simulated by the subroutines. That figure and this discussion are given to assist a user in writing a control program and not necessarily to be rigidly adhered to.

The first step in the operation of the control program is to read the input parameters into common areas and read the first geology parameters. The control program then calls each subroutine which has an initialization entry (see the flow charts) for initialization of parameters not read in, and initializes the old working parameter common (OLDCOM) area so it portrays the proper initial state for start of processing.

For each time step in the simulation, a check is first made as to whether the tunnel has progressed to the point where new geology information is needed. If this is the case, new geology information is read into common overlaying the old information.

Each subroutine is called for its normal entry point. Note that subroutines for one element (e.g., rock disintegration) may be order-dependent and should be ordered as they are listed in Fig. IV-4. The order in which the elements are called does not matter.

After all routines have been called, the resulting information in the new working parameter common area is then copied into the old working parameter common area. Also, heading position and time are updated. The control program then interrogates the flags* in the old-working-parameter common area and determines the status of the rock disintegration process in the next cycle. This is done in the control program for flexibility.

---

*Previously called status variables.

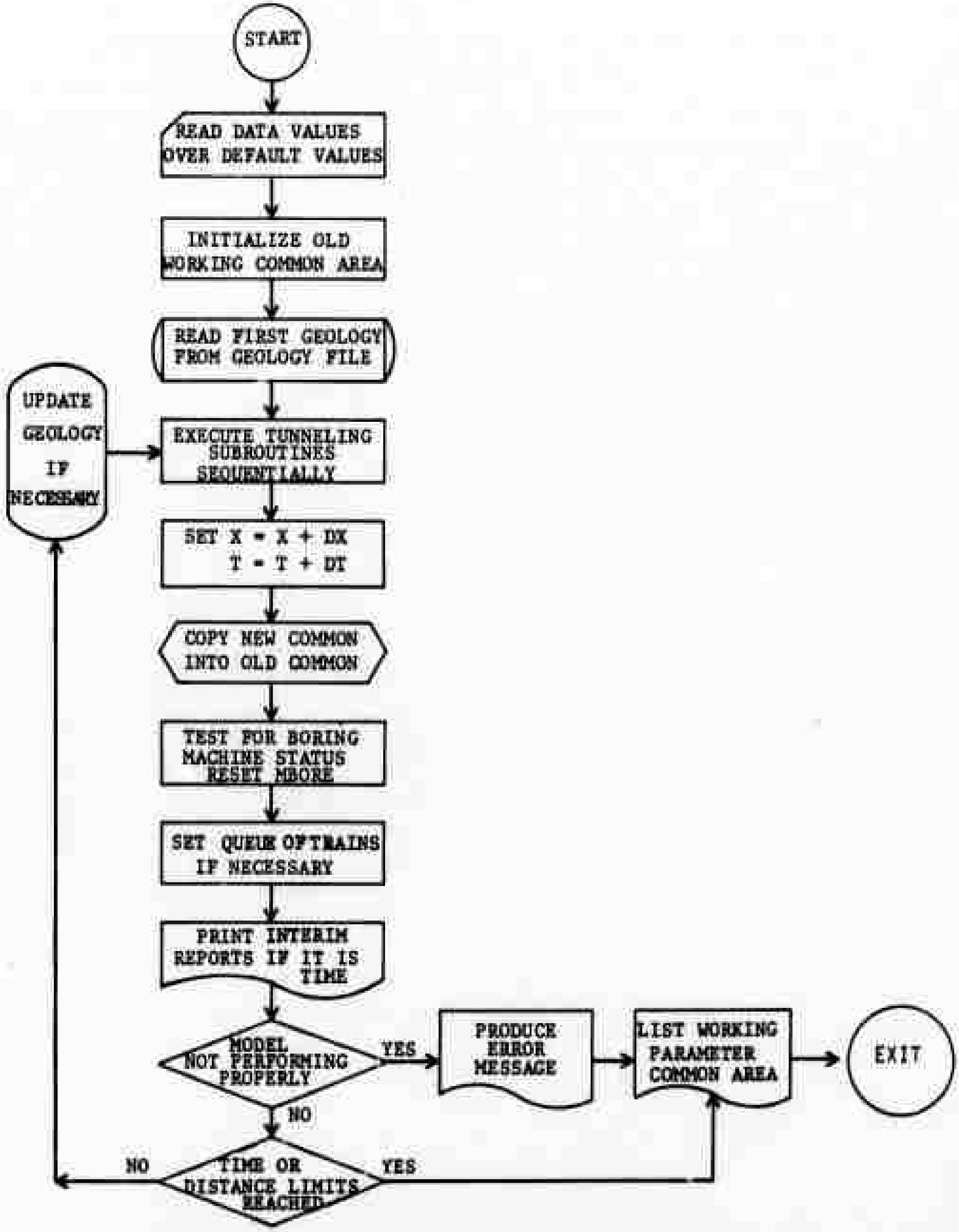


Figure IV-4. Overall Logic of a Control Program for the Tunneling Model

The rock disintegration process is the lead process; it determines the heading advance and the muck created. Other elements follow it automatically, given its progress. The rock fragmentation process, however, must be informed through flags set by the other elements what state it should be in (with the exception of its own maintenance). Looking at these flags in the control program gives the user more flexibility in determining how the excavator reacts to other elements.

The control program also handles the queuing of the long-haul materials-handling element if it requires queuing. The queuing is handled here to retain the order independence of the elements.

The control program's next step is to determine whether output reports are desired at this point and to call routines to produce them. Note that these reports can be spaced in any desired manner with respect to time, length along the tunnel, or whatever. There is no restriction as to how reports are generated.

After output report checking is performed, a check is made to determine if the model should be ended; this would usually be equivalent to asking if the time or distance limits input have been exceeded. If this is the case, the simulation is ended with a printout of working common variables needed to restart the model at the heading position reached. If the simulation is not to be ended, another time step is started by checking to determine if new geology parameters are needed.

The tunneling activities which are being coordinated by the control program are, as previously stated, embodied in subroutines; one or more of these routines made up a process such as boring machine rock fragmentation. In any simulation one and only one process for each of the following tunneling elements should be included:

1. Rock fragmentation
2. Materials handling (long haul)
3. Materials handling (short haul)
4. Ground support
5. Environmental control

Descriptions of the sets of routines representing the processes available for each element are given in Sec. II.

The user should use the preceding discussion of the control program as a guide in writing his own program. The control program written for the Layout Tunnel which actually consists of several subroutines and a control program is described in the next section and should be studied for further information on writing a control program.

V. CREATING A CONTROL PROGRAM FOR THE LAYOUT TUNNEL

As mentioned in Sec. I, the various tunneling activities are simulated by modular subroutines. The simulation of an entire excavation project can therefore be made by using a building-block technique. Ideally, the program that analyzes a given project would consist of all the subroutines that are pertinent to the simulation and a driver (main) program that ties them together. The subroutines are ideally independent of each other in function and in logic, so that they are not order-dependent in their usage by the main program. This section is concerned with the construction of a control program and secondary input and output routines to initialize data and report results, and discussion will be restricted to a sample control program that simulates the excavation of the Strawberry Aqueduct Layout Tunnel.

A. SUBROUTINES

The tunneling subroutines needed for the Layout Tunnel simulation are as follows:

Element and General Process	Activity	Subroutine Entry Initialization/Normal
Rock fragmentation, boring machine	Bore	BORE/BORER
	Cutter change	CUTTER/CUTCHG
	Maintenance	REPAIR/MAINT
Materials handling, conventional rail system	Train logistics	RAILHL/RAILTR
	Track laying	RAILEX/RAILXT
	Discharge	RAILDS/RAILDS
	Train maintenance	RAILMT/RAILMT
	Loading	CVLOAD/LOADCV
	Loader maintenance	CVMNT/CVRPR
Ground support	Rock bolts, etc.	GRNSUP/GROUN
	Equipment maintenance	GSMAIN/GSMNT
Environmental control	Ventilation and cooling	ENVIR/ENVIRC

B. SUBROUTINE USAGE

After proper initialization of data (see Sec. V-D below), each excavation subroutine is called once for each time station T. The time stations are equally spaced at DT, which is input. Each subroutine calculates the progress made in the time DT and sets a flag indicating the status of the progress. For example, CUTTER calculates the incremental cutter wear for the time DT and the cumulative cutter wear up to time T. If one or more cutters have exceeded the maximum-wear criterion (an input), a flag LNCUTR is set to 1. Otherwise, LNCUTR is set to 0. The boring machine is then turned on or off depending on whether LNCUTR is zero or nonzero. As another example, CVLOAD simulates the muck loading activity. The volume of muck created in DT depends on the hardness of the rock and the boring machine operating characteristics. At the end of DT, the muck is assumed loaded onto the trains via the loader. If the train is full, it is sent on its way to the discharge area, and another train (if one is available in the load queue) is moved into the loading area. A flag LOADR is set to 0 in this case. If, however, there is no train available for loading, LOADR is set to 1 which indicates that the boring machine should be turned off until a train becomes available for loading. A control program that simulates the excavation process as a whole must interrogate all the flags (see Table IV-2) set by all the subroutines and then decide on what status the boring machine should have.

C. CONTROL LOGIC

The essential features of the control logic for the sample control program are shown schematically in Fig. IV-5. Note that the rock fragmentation activity BORE/BORER is controlled by the flag MBORE. In general, the boring machine is turned off any time any of the support activities cannot keep up with the rate of advance of the boring machine or if any

TABLE IV-2

DEFINITION OF FLAGS SET IN EXCAVATION MODEL

SUBROUTINE	FLAG		OPTIONS
BORE	MBORE	= 0	normal operation - boring machine going full speed
		= 1	boring machine in maintenance
		= 2	boring machine cutters being changed
		= 3	mil extension rate exceeded
		= 4	new switch being added
		= 5	switch being moved up
		= 6	no train available for loading
		= 7	ground support construction rate exceeded
		= 8	loader in maintenance
CUTTER	LNCUTR	= 0	normal operation--no cutter change needed
		= 1	cutter change started
		= 2	cutter change still in progress
REPAIR	MBM	= 0	normal operation--no maintenance needed on boring machine
		= 1	boring machine due for maintenance
ASSMBL	MASSEM	= 0	normal operation--boring machine assembly completed
		= 1	boring machine assembly in progress
DISASM	MDISAS	= 0	normal operation--boring machine disassembly completed
		= 1	boring machine disassembly in progress

TABLE IV-2 (cont.)

DEFINITION OF FLAGS SET IN EXCAVATION MODEL

SUBROUTINE	FLAG		OPTIONS
RAILTR	LSTOP	= 0	normal operation--continue system
		= 1	shut down system--external reasons
		= 2	bring up system--external reasons
RAILDS	IFILD	= 0	normal operation
		= 1	discharge area filled
CVLOAD	LOADR	= 0	normal operation
		= 1	no train available for loading
CVMNT	LMCV	= 0	normal operation
		= 1	loader maintenance in progress
CVMNT	LMFLAC	= 0	normal operation
		= 1	loader turned off for external reasons
GRNSUP	IEXCA	= 0	normal operation
		= 1	ground support construction rate exceeded
RAILEX	NBYBY	= 0	normal operation
		= 1	rail extension rate exceeded
RAILEX	NSWCH	= 0	normal operation
		= 1	new switch to be added
		= 2	switch to be pushed forward
CVLOAD	IEXCAV	= 0	normal operation
		= 1	boring machine turned off, loader in maintenance

TABLE IV-2 (cont.)

DEFINITION OF FLAGS SET IN EXCAVATION MODEL

SUBROUTINES RAILTR, RAILDS, RAILEX

LTSTAT	= 0	stopped, empty
	= 1	stopped, full
	= 2	accelerating, empty
	= 3	accelerating, full
	= 4	going full speed, empty
	= 5	going full speed, full
	= 6	decelerating, empty
	= 7	decelerating, full
	= 8	in switch, empty
	= 9	in switch, full
	= 10	in discharge area
	= 11	in maintenance area
LKSTOP	= 0	not stopped
	= 1	at face, being loaded
	= 2	in switch, train ahead
	= 3	in switch, train approaching
	= 4	external reasons
	= 5	in switch, waiting to enter discharge area
	= 6	in switch, waiting to enter load queue
	= 101	in load queue, 1st in line
	= 102	in load queue, 2nd in line
	= n	in load queue, (n-100)th in line
LLVHCL	= 0	no train in load area
	= n	train #n is in load area

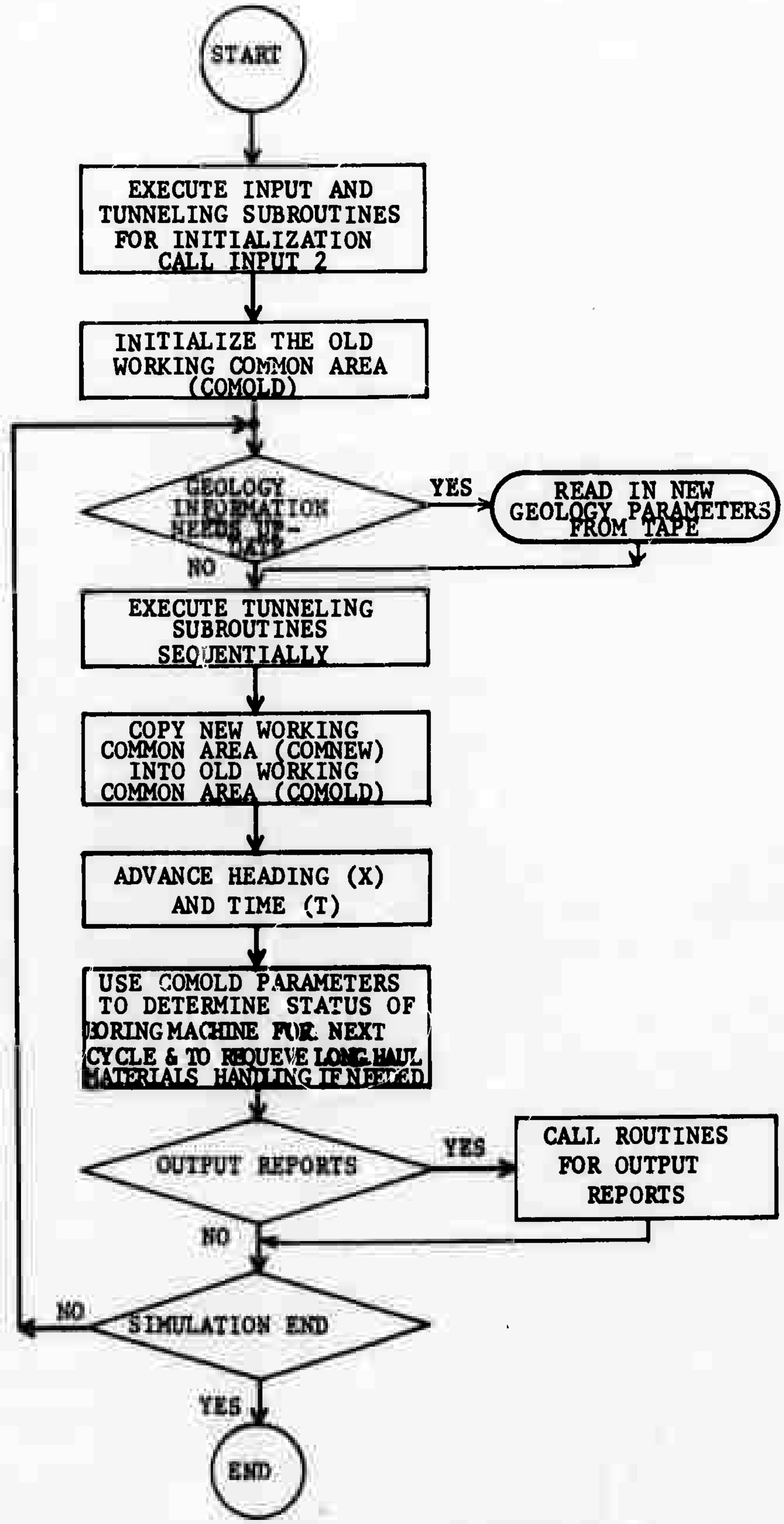


Figure IV-5. Logic of the Control Program for the Layout Tunnel of the equipment becomes unavailable because of maintenance requirements. Note also that the boring activity is not resumed unless all of the support activities have caught up with the rock fragmentation process. In other words, boring is the pivotal activity that is affected by all the other activities. The flag MBORE is therefore set according to the table shown below.

MBORE	CONDITION
0	normal operation: boring machine is going full speed
1	no advance: boring machine is in general maintenance
2	no advance: boring machine cutters are being replaced
3	shut-down boring machine: rail extension rate has been exceeded
4	shut-down boring machine: a new switch is being added
5	shut-down boring machine: switch needs to be moved up
6	shut-down boring machine: there is no train available for muck loading
7	shut-down boring machine: ground support activity has fallen behind
8	shut-down boring machine: muck loader is in maintenance

One of the tasks required of the control program is to make certain that the boring machine is not turned on unless the flags from all the subroutines indicate that boring activity should be turned on. This means a series of tests must be made of the flags from all the subroutines and that the boring machine flag MBORE must be set and reset in accordance with these flags.

Another task required of the control program is to move the trains up in the load queue when it is time to do so. The reason that this task is given to the control program is that several conditions have to be satisfied before a train can be moved up. First of all, the train that is currently being loaded must be full. This is tested in subroutine CVLOAD. Then the rail extension activity must be able to keep up with the boring activity. This is tested in subroutine RAILEX. Then the installation of a new switch must be complete if one is needed before a train can move up the load queue. This is also tested in subroutine RAILEX.

A third task required of the control program is to insure that RAILTR is called before any of the other rail subroutines which include CVLOAD and RAILEX. The reason for this requirement is that RAILTR is the subroutine that controls the dynamics of the trains. Since the speed of the trains is on the average several orders of magnitude greater than the rate of excavation, a time interval DT compatible with the excavation activity would be too great for the rail activity. Therefore, RAILTR divides the time interval DT into many subintervals such that no train would have moved more than 50 feet in any one subinterval. The position and the speed of the trains can thus be simulated more realistically. But since different trains would be doing different things at different subintervals, the only way to keep the logic tractable is to update the status of <u>all</u> the trains at the end of DT: i.e., the status flags of all the trains are reset at the end of DT. Now if another rail subroutine is called before RAILTR and if that subroutine resets the flag of one of the trains, that result would be nullified by RAILTR.

A last task of the control program is to produce reports by calling output routines written for the Layout Tunnel (REPORC, REPORS, and OUTPUT) at intervals specified by the user, and to call MAXADV once each day to determine the daily advance (see Sec. V-E below).

D. INITIALIZATION OF DATA

The initialization of data for the simulation is handled by the control program and a subroutine INPUT written to accompany the control program. Figure IV-6 shows the initialization sequence.

Two types of data need to be initialized:

1. Geology parameters which give the geology characteristics along the tunnel. These parameters are on a tape (logical unit 40; see listings in Appendix II). See Appendixes II and III for a description of the creation of this tape. The routine INPUT reads the first parameters from the tape. Then the control program tests at the start of each time interval to determine if a new set of parameters is needed. When one is needed the control program reads a new set.

2. Parameters for each general process and a set of parameters which apply to all processes, such as initial reading, initial time, and time step length. These parameters are read in at the start of each run by INPUT. The FORTRAN NAMELIST data reader capability is used by INPUT for reading in the cards. A special provision is made for reading in a primary ground support table (described in Sec. II-E above). This table is read in on cards in fixed format (9F8.2; see listing in Appendix II) if the user wishes to input his own table.

After INPUT has read in all parameter cards, the control program calls each general process subroutine by its initialization entry. In each routine parameters for the general process will be compared to 0; if found equal to 0, they are then given a default value. Parameters not dealt with in this way will have a default value of 0 if not read in. INPUT then prints out a list of all parameters with the value read in or the default value.

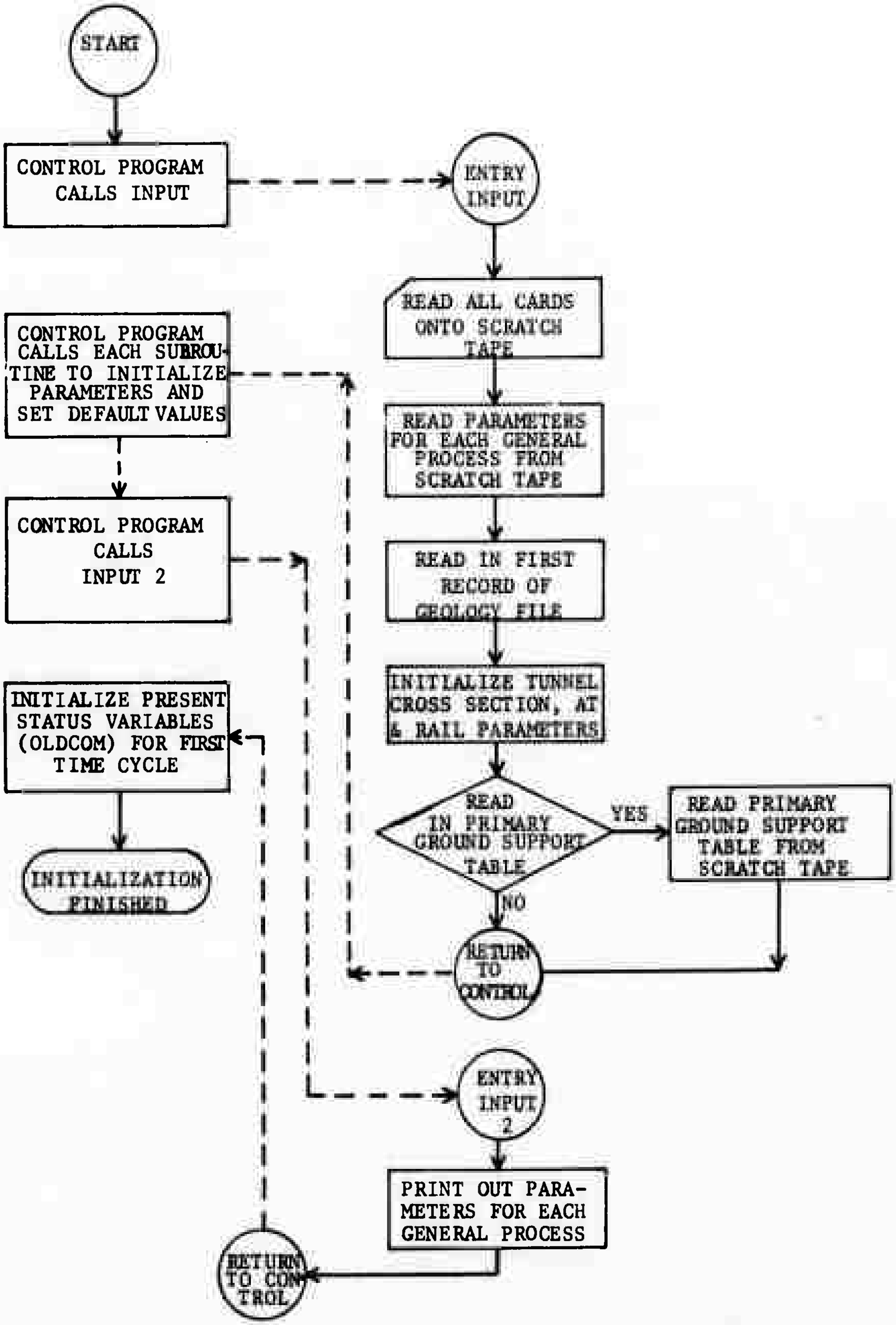


Figure IV-6. Initialization Sequence for Layout Tunnel

Finally, the control program initializes the working common area (OLDCOM) for the first time step.

E. OUTPUT

The output for the Layout Tunnel is of two kinds: (1) a printout of common variables, and (2) interim cost and performance reports. It is handled by subroutines which are called by the control program.

1. OUTPUT - prints out common variables from the various subroutines and from OLDCOM. These parameters show the status of the different general processes at an instant in time. A sample of this printout is shown in Fig. IV-7. The routine is called by the control program at time intervals (DTPRNT) input by the user. It is also called at the end of a run to print out variables to be used for restarting the model at that point.

2. MAXADV - The routine computes each day's advance and saves values for the maximum advance.

3. REPORR - rints cumulative performance figures for each element (subsystem). The performance figures are computed as follows:

   Subsystem availability = (shift time - down time)/shift time

   Subsystem utilization = operating time/shift time

   Shift time = 24 hours in Layout Tunnel. Can be input by user (TSHFT)

```
T=       0.          X=       5.400E+01   IA=        2   STR=    1.200E+01   DX=       0.              MBM=      0
LNCUTR=    0    NBYBY=    0   NSWCH=     0   MBORE=     0   LOADR=     0   NUMSWT=    1   IEXCA=     0   MCV=        0   MFLAGC=   0

IEXCAV= 0.          MGS(2)= 0.          MGS(3)=    0   MGS(4)= 0.                  0.

CUTTER WEAR...
0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
0.       0.       0.       0.       0.       0.       0.       0.       0.
TRAIN NO. 1....STOPPED, EMPTY      AT FACE, LOADING    X =-5.3100E+02 FT   V = 0.        MPH   DSM =   0.0000    0    1
TRAIN NO. 2....STOPPED, EMPTY      AT FACE, IN QUEUE   X =-5.3100F+02 FT   V = 0.        MPH   DSM =   0.0000    0  101
TRAIN NO. 3....STOPPED, EMPTY      AT FACE, IN QUEUE   X =-5.3100E+02 FT   V = 0.        MPH   DSM =   0.0000    0  102

GROUND SUPPORT AT     54.000
ENVIRONMENTAL CONTROL    ODR=       0.00
```

Figure IV-7. Printout of Working Storage

Down time and operating time are computed in subroutines for each general process and cumulated in the following variables:

Element - Subroutine	Operating Time	Down Time
Rock disintegration (BORE)	RDUTIM	RDDTIM
Materials handling (CVMNT, RAILHL)	UMHTIM	DMHTIM
Ground support (GRNSUP, GSMAIN)	GSUTIM	GSDTIM
Environmental control (ENVIR)	ECUTIM	ECDTIM

The status variables in Table IV-2 are used to determine in each time step whether the element is operating, down, or neither (idle) for the time interval (DT) in the following manner:

Element	Down	Action Taken	Operating	Action Taken
Boring machine	MBORE > 0 and MBORE ≤ 3	RDDTIM = RDDTIM + DT	MBORE = 0	RDUTIM = RDUTIM + DT
Materials handling rails, conveyor loader	NUMLD = 0 or MCV = 1	DMHTIM = DMHTIM + DT	NUMLD ≠ 0 & MCV = 0	UMHTIM = UMHTIM + DT
Ground support	MGS(I) = 1 where I is support type using	GSDTIM = GSDTIM + DT	MGS(I) = 0 and ground support can proceed (not too close to face)	GSUTIM = GSUTIM + DT
Environmental control	Never		Always	ECUTIM = ECUTIM + DT

See Sec. III of this appendix for further information on handling availability and utilization values for simulation. In Fig. IV-8 a sample of this report is shown.

DAYS SINCE COMMENCED EXCAVATING	2.000
HEADING POSITION(FEET)	352.686
AVERAGE ADVANCE RATE(FEET/OPERATING HOUR)	12.764

MAXIMUM DAILY ADVANCE

DAYS SINCE COMMENCED EXCAVATING	2.000
HEADING POSITION-BEGINNING OF THAT DAY(FEET)	207.172
HEADING POSITION-END OF THAT DAY(FEET)	352.686
AVERAGE RATE FOR THAT DAY(FEET/OPERATING HOUR)	12.764

CUMULATIVE SUBSYSTEM PERFORMANCE..

ELEMENT/MEASURE	OPERATIONAL AVAILABILITY*	SUBSYSTEM UTILIZATION**
ROCK FRAGMENTATION	.500	.488
MATERIALS HANDLING	.992	.488
GROUND SUPPORT	1.000	1.000
ENVIRONMENTAL CONTROL	1.000	1.000

*OPERATIONAL AVAILABILITY=(TOTAL SHIFT TIME-DOWN TIME)/TOTAL SHIFT TIME

**SUBSYSTEM UTILIZATION=(TOTAL SHIFT TIME-DOWN TIME-IDLE TIME)/TOTAL SHIFT TIME

Figure IV-8. Interim Performance Report

4. REPORC - prints out cumulative cost values. The cost values are computed for each general process in one of its subroutines (see Sec. III above for a description of variables used). They are cumulated in parameters in COMMON/MONEY/. Totals and overhead costs are recalculated each time REPORD is called. See Fig. IV-9 for a sample of the cost report.

Both REPORS and REPORD (normal entry points for REPORR, REPORC) are called at time intervals specified by the user with input parameter REPORT.

DAYS SINCE COMMENCED EXCAVATING	2.000
AVERAGE COST PER IN SITU CUBIC YARD EXCAVATED	19.82
AVERAGE COST PER FOOT OF TUNNEL	96.19

CUMULATIVE COST SUMMARY TO DATE..(DOLLARS)

ELEMENT/CATEGORY	DIRECT LABOR	PLANT + EQUIPMENT	JOB MATERIALS	PERMANENT MATERIALS	OVER-HEAD	ELEMENT TOTAL
ROCK FRAGMENTATION	2153.76	11350.08	809.48	0.00	1431.33	15744.65
MATERIALS HANDLING	4673.76	1899.08	153.03	0.00	672.59	7398.46
GROUND SUPPORT	3379.20	0.00	0.00	0.00	337.92	3717.12
ENVIRONMENTAL CONTROL	1398.24	298.69	2.80	0.00	169.97	1869.70
CATEGORY TOTAL	11604.96	13547.85	965.31	0.00	2611.81	28729.93

Figure IV-9. Interim Cost Report

APPENDIX V

LAYOUT TUNNEL DATA

by

L. M. Pietrzak and W. R. Thomson

SUMMARY

This appendix contains data acquired from the Bureau of Reclamation and other sources concerning the first 5,038 feet of the Layout Tunnel, a part of the Strawberry Aqueduct Project. The tunnel was driven between June 25 and September 22, 1971. Geological reports, machinery specifications, and progress records are included.

ACKNOWLEDGMENTS

The information found in this appendix was kindly supplied by Mr. Booneymixon of the S. A. Healy Co., Project Engineer for the Layout Tunnel; A. S. D'Alessandro, Contruction Engineer in the central Utah Projects Office for the Bureau of Reclamation; Ray Moran of Moran Engineering Co. which fabricated the muck cars and the loading and unloading equipment; and Don Shaver of Plymouth Locomotive Works which fabricated the train locomotives. H. F. Haller of Holmes and Narver supplied data on rock properties and muck characteristics.

CONTENTS

I. <u>EQUIPMENT AND SYSTEM DESCRIPTION</u>

The Layout Tunnel is a part of the Strawberry Aqueduct Project and was driven in the summer of 1971 near Heber City, Utah. S. A. Healy Company is excavating Layout and Currant Tunnels with a Robbins Co., Model No. 141-127-1, excavating machine ("the male") previously used to excavate a tunnel in the Chicago, Illinois, area. The machine was rebuilt and modified by Robbins Company, 651 S. Orcas, Seattle, Washington. The first section arrived at the work site May 24, and the mole was assembled during the rest of May and June near the outlet portal of Layout Tunnel. Approximately 1,670 man-hours were used to assemble the machine, which is 45 ft long and weighs approximately 200,000 lb. The last shipment of the integrated conveyor loader was delivered to the site at the end of July 1971.

The mole cuts a 12 ft 11 in. diameter tunnel. The rotating head consists of a center tri-disc cutter with a series of 29 disc cutters. The tri-disc center cutter is a cluster of three disc mounted on one shaft. The cutters are numbered from the center out. The cutters are spaced radial as follows: cutters No. 1 through 8, 2-7/8 in.; cutters No. 9 through 21, 2-3/4 in.; cutter No. 22 is 2-11/16 in. from No. 21; cutter No. 23 is 2-1/2 in. from 22; cutters No. 24 through 27 are spaced at 2-1/8 in.; cutter No. 29 is spaced at 1-1/4 in. from No. 27 and gage cutter No. 29 is 1-1/4 in. from No. 28.

The maximum thrust on the head is 892,000 lb with a propel pressure of 3,500 psi. The thrust rating for each of the four drive arms is 223,000 lb at 3,500 psi. The contractor has operated with propel pressure between 1,800 and 2,600 psi.

The mole is powered by six 100 hp, CJ5NB Pacemaker, 440 volt electric motors. These motors create a rated torque of 630,240 ft•lb. Electricity is delivered to the mole at 7,200 volts and transformed to 440 volts through a transformer located at the rear of the mole. Electricity to operate the mole is obtained from commercial supplier, Moon

Lake Electric. The mole is held in place while excavating by two hydraulic powered side grippers, immediately behind the cutter head.

The excavated material was hauled from the tunnel to an 800 ft long dump site located 12,000 ft from the outlet portal. Three trains of ten, 6 2/3 yd^3 (struck) side dump cars, pulled by two 10-ton diesel powered Plymouth Mine-o-motive, GA-24, Model DMD-24 locomotives were used. The track gauge was 24 in., and rail weight 65 lb per linear yard.

The mucking equipment included an integrated 24 in. troughed belt conveyor, and a California switch for train switching that extended 765 ft behind the boring machine. This configuration is shown schematically in Fig. V-1.

The normal sequence for loading and muck removal starts with three trains in the loading area, i.e., one in the loading position, and the others waiting in the California switch. Once loaded the first train departs for the discharge area, and an empty train moves into the loading position. Thereafter, at any given time one train would typically be loading while one is waiting to be loaded and the third is on its way to the discharge area for dumping. The cars returning from the discharge area carry men and materials to the face as needed.

Other than the California switch at the face, there are no switches between the discharge area and the near face zone. Only one train can occupy the track between the loading and discharge area at any given time. This situation applies for the first 8650 ft of tunnel which includes the entire segment being considered for computer simulation at this time.

In the discharge area, each muck car is dumped individually using side dump equipment that runs on a track parallel to the main line track, dumping each car as it proceeds.

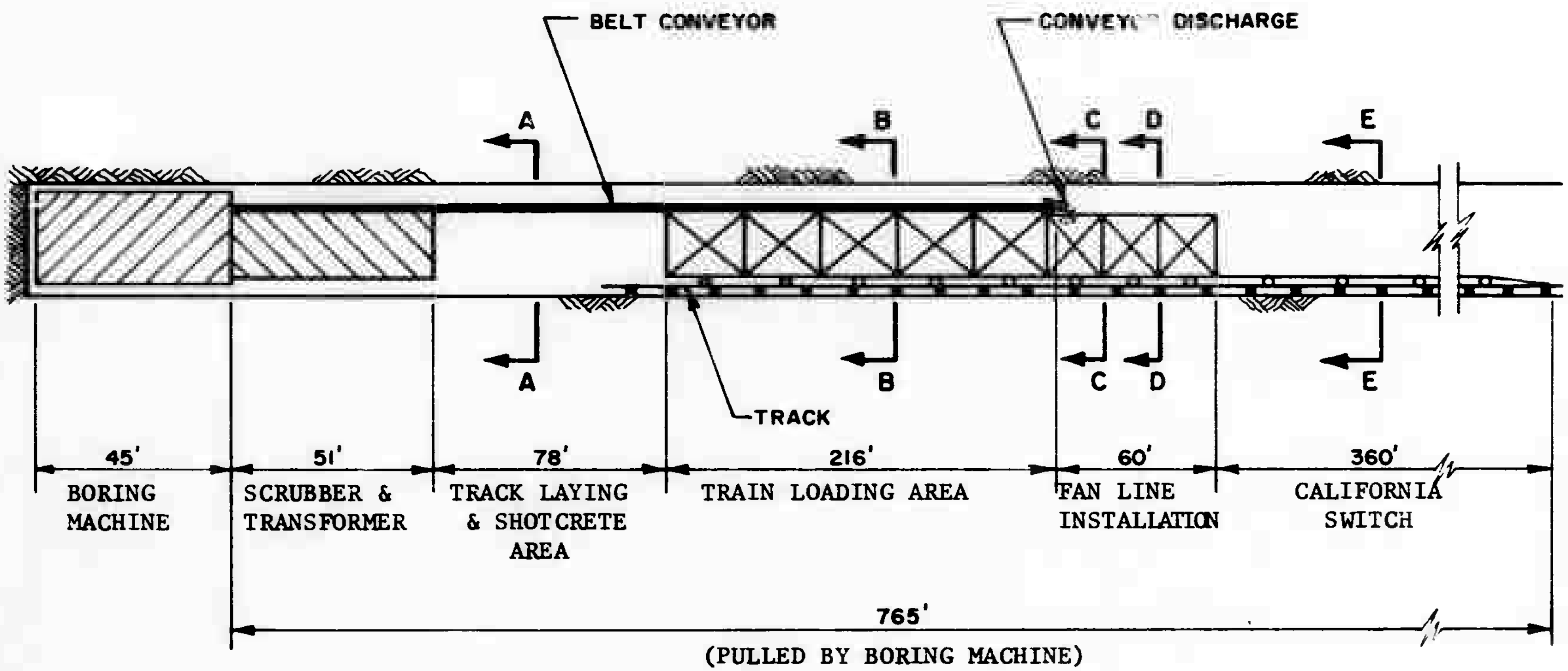


Figure V-1. Muck Loading Equipment Configuration Used in Layout Tunnel (Courtesy of Moran Engineering Co.)

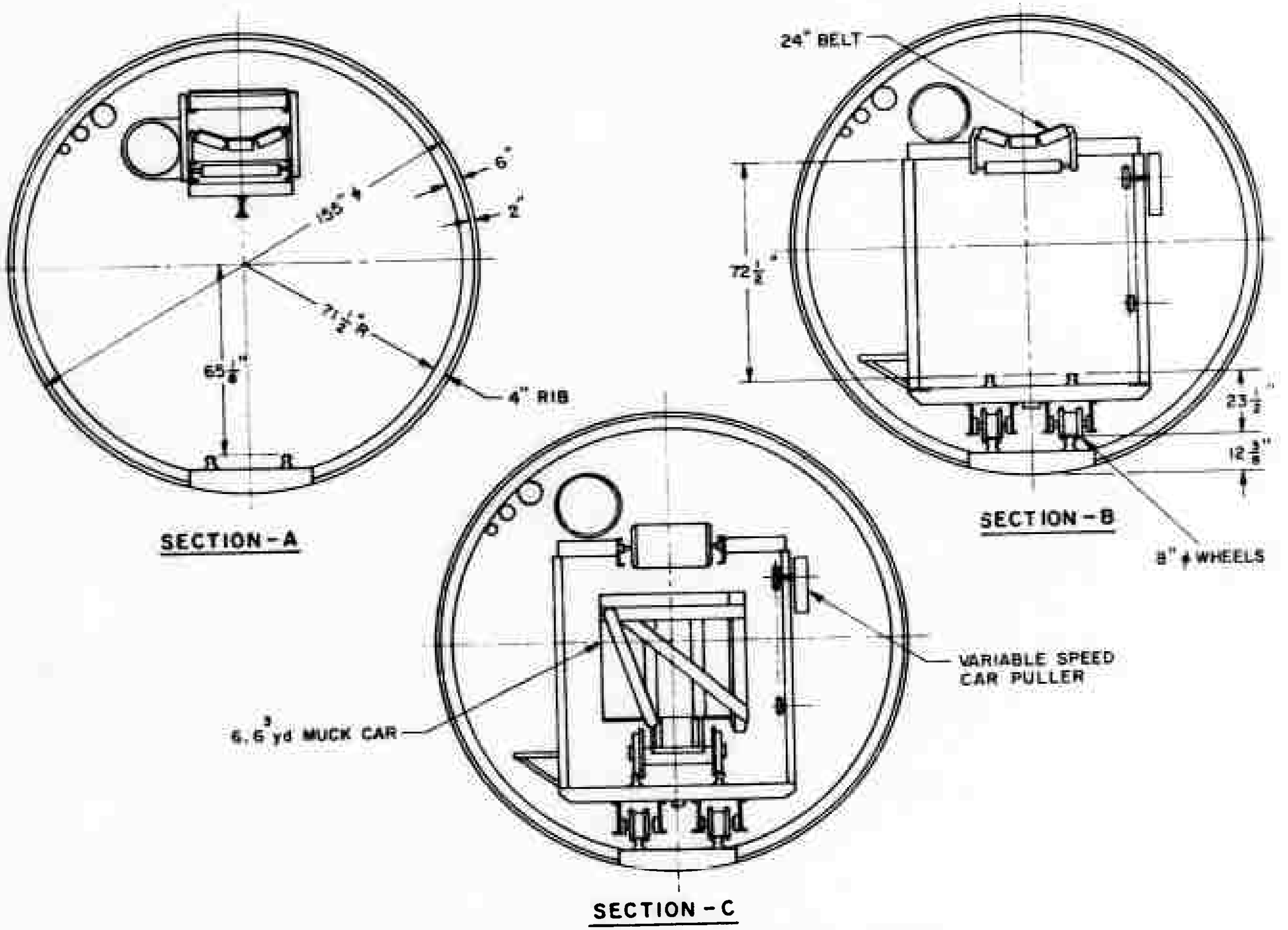


Figure V-1. Muck Loading Equipment Configuration Used in Layout Tunnel (Cont.)

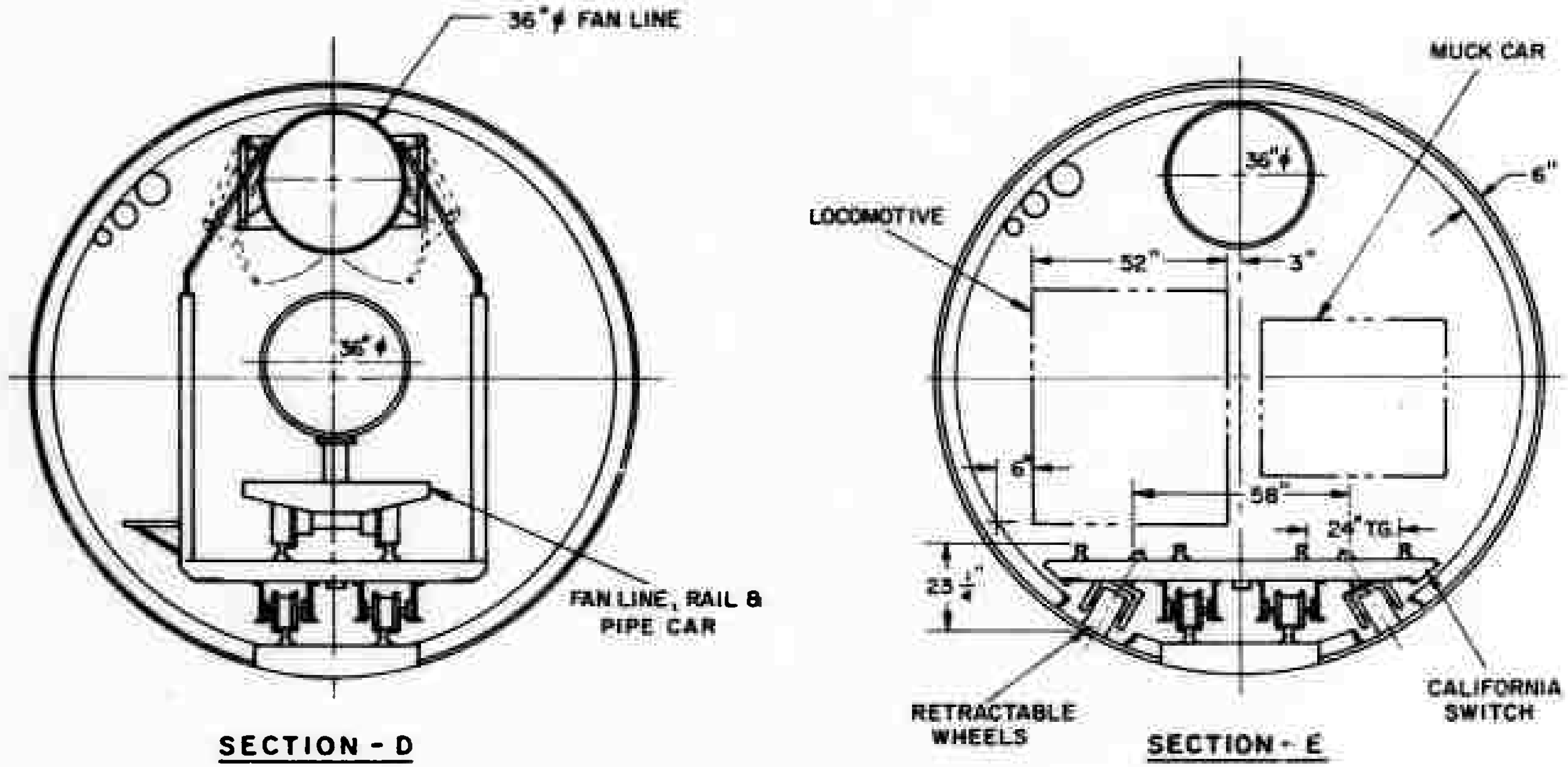


Figure V-1. Muck Loading Equipment Configuration Used in Layout Tunnel (Cont.)

Dust removal and ventilation is accomplished by drawing air from the near-face loading and working area (17,000 cfm at 2405 fpm) through a 36 in. diameter fan line. The equipment includes an Elbair scrubber in the near-face zone and a 100-hp fan motor that supplements a portal fan.

Ground support includes steel ring sets, rock bolts, cribbing and lagging, and shotcrete as required. Actual support installation for the 5038 ft segment is described in the June 29 progress reports summarized in Sec. III of this appendix.

II. GEOLOGY

A. GEOLOGY REPORTS

Date	Station	Geology
6/25/71	1786+26 - 1786+20	Layout Tunnel: Rock is a firm, medium hard, brown sandstone. Dip = 2-3° downstream. Rock is tight and impermeable.
6/28/71	1786+20 - 1785+93	Browr sandstone (medium hard) is periodically cut by lenses of soft, gray, porous sandstone.
6/29/71	1785+93 - 1785+61	Three vertical joints (cracks) at springline at Station 1785+00, LW (left wall) 1 to 2 ft long.
6/30/71	1785+61 - 1785+26	Periodic short vertical joints continue upstream.
7/1/71	1785+26 - 1784+55	Normal entry of formations into tunnel bore is at invert and rising upstream into roof. However, conglomerate enters from roof and trends upstream erratically.
7/2/71	1784+55 - 1783+93	At Station 1784+40 a very hard, well-cemented conglomerate starts in roof. It contains a 3 in. maximum quartzite rock. Conglomerate is lightly fractured and is dripping water.
7/3/71	1783+93 - 1783+41	Vertical joints at Stations 1783+25, 1783+50, 1783+45, all dripping water. No support steel thus far.
7/6/71	1783+41 - 1782+91	

Geologic Material (Cont.)

Date	Station	Geology
7/7/71	1782+91 - 1781+33	Hard conglomerate is now a 4 ft bed at springline with the previously mentioned brown sandstone (medium hard) above and below.
7/8/71	1781+33 - 1780+04	Brown sandstone is interbedded with thin (1-2 in.) brown shales that push out when wet and dried. Mole gripper pads leave small chips and fractures near springline.
7/9/71	1780+04 - 1778+43	Beds dipping downstream 2-3°. Conglomerate (very hard) is now in middle of tunnel near springline.
7/10/71	1778+43 - 1777+89	Brown, silty sandstone (medium hard) is above and below conglomerate and has thin brown shales.
7/12/71	1777+89 - 1777+19	Formations dip 2-3° downstream.
7/13/71	1777+19 - 1776+23	Hard conglomerate is grading upstream into a gray, medium hard sandstone. Gray sandstone contains lenses and thin beds of pebble conglomerates.
7/14/71	1776+23 - 1775+17	Medium hard, brown sandstone becoming fractured with short, closely-spaced joints.
7/15/71	1775+17 - 1774+32	
7/16/71	1774+32 - 1774+01	Loose, channel-fill zone, Stations 1771+30 to 1775+00, a very loose, soft section containing poorly-cemented sandstones with gravel streaks.

Geologic Material (Cont.)

Date	Station	Geology
7/17/71	1774+01 - 1773+87	Above mentioned zone is wet and contains many joints and fractures due to close proximity to fault west of tunnel.
7/19/71	1773+87 - 1773+73	
7/20/71	1773+73 - 1773+59	
7/21/71	1773+59 - 1773+13	
7/22/71	1773+59 - 1772+82	Same conditions as above
7/26/71	1772+82 - 1772+39	Many seeps.
7/27/71	1772+39 - 1771+86	
8/3/71	1771+86 - 1770+56	Joint, filled with white calcite RW: 1770+90, LW: 1770+80. Rock is half hard sandstone and half soft poorly-cemented tan sandstone.
8/4/71	1770+56 - 1769+38	Soft tan sandstone has drips and many fractures.
8/5/71	1769+38 - 1768+56	Whole tunnel is soft, tan sandstone. Rock is firm, medium-hard sandstone at Station 1769+00.
8/6/71	1768+56 - 1767+50	
8/7/71	1767+50 - 1767+50	
8/9/71	1767+50 - 1765+95	Top half of tunnel is medium-hard brown sandstone; bottom half is soft, wet tan sandstone, containing thin shale. Light fallout along thin shales near springline.

Geologic Material (Cont.)

Date	Station	Geology
8/10/71	1765+95 - 1765+70	Fault Zone - Station 1763+42 to 1766+10
8/11/71	1765+70 - 1765+34	Fault is considered to be a side fracture off larger fault located west of tunnel and bearing nearly parallel.
8/12/71	1765+34 - 1764+87	Fault Zone: Stations 1763+42 to 1766+10 Rock is broken mass of soft sandstone and conglomerate. Broken rock is mixed in with a wet mixture of sand and clay.
8/13/71	1764+87 - 1764+01	
8/14/71	1764+01 - 1764+01	4 in. circular steel H-beam supports were installed throughout fault zone because of loose, unstable condition of tunnel walls.
8/16/71	1764+01 - 1763+04	
8/17/71	1763+04 - 1762+05	Rock is medium-hard, brown sandstone containing thin shales.
8/18/71	1762+05 - 1759+96	Vertical joint at 1761+90, with many small fractures.
8/19/71	1759+96 - 1758+02	At Station 1759+00 sandstone grades into hard conglomerate top half of tunnel. Bottom half is soft, tan sandstone containing thin shales.
8/20/71	1758+02 - 1757+43	Conglomerate and sandstone has many small fractures that are dripping water.
8/21/71	1757+43 - 1757+43	Conglomerate pinches out in roof at Station 1757+95. Occasional vertical joints and many small fractures.

Geologic Material (Cont.)

Date	Station	Geology
8/23/71	1757+43 - 1756+57	Top half is medium-hard brown sandstone with thin shales--bottom half is a soft sandstone.
		Conglomerate enters in roof.
8/24/71	1756+57 - 1755+07	Tunnel bore all hard conglomerate with lenses of soft sandstones.
8/25/71	1755+07 - 1753+35	
8/26/71	1753+35 - 1752+75	Rock is mostly hard conglomerate with lenses of soft sandstone.
8/27/71	1752+75 - 1751+68	Conglomerate has few lumps of shale.
8/28/71	1751+68 - 1751+68	Conglomerate has many fractures and joints from Station 1756+50 to 1756+00.
8/30/71	1751+68 - 1750+68	
8/31/71	1750+68 - 1749+55	Top half of tunnel is medium hard, sandstone; soft, tan sandstone in bottom.
		Many small fractures and a few vertical joints.
9/1/71	1749+55 - 1748+69	
9/2/71	1748+69 - 1747+46	Tunnel rock is all a soft brown sandstone with thin shales.
		Small amount of fallout in thin shales.
9/3/71	1747+46 - 1746+20	
9/7/71	1746+20 - 1745+49	Soft, brown, poorly-cemented sandstone.

Geologic Material (Cont.)

Date	Station	Geology
9/8/71	1745+49 - 1744+56	Many joints, and fractures with 5 gal/min water in joint at Station 1745+20 RW.
9/9/71	1744+56 - 1743+90	Fallout in soft, fractured sandstone.
9/10/71	1743+90 - 1743+30	
9/13/71	1743+30 - 1742+38	Gray and tan, soft sandstone with thin brown shales. Many small vertical fractures throughout.
9/14/71	1742+38 - 1741+34	Fallout along shales near springline.
9/15/71	1741+34 - 1740+65	
9/16/71	1740+65 - 1739+86	
9/17/71	1739+86 - 1739+02	Tunnel rock is harder. Sandstone is better cemented.
9/20/71	1739+02 - 1738+17	Fewer joints and fractures than downstream.
9/21/71	1738+17 - 1736+77	Note: Because of nearby fault paralleling tunnel to west, tunnel throughout has many joints and fractures. There are short sections of tunnel supported with steel.
9/22/71	1736+77 - 1736+60	Longer supported sections include soft, channel-fill from Station 1771+30 to 1775+00, the fault zone from Station 1763+42 to 1766+10. The last 1700 ft of tunnel (Stations 1736+60 to 1752+60) is fractured and jointed and is 60% steel supported.

B. ROCK PROPERTIES AND MUCK CHARACTERISTICS

The following information was acquired by Holmes and Narver Inc. as part of the Muck Designation Study under Contract No. H0210013 of the ARPA program. The rock properties cited are for a rock sample taken 4,100 ft from the tunnel portal.

PROJECT & LOCATION	OWNER OR AGENCY	SIZE	LENGTH	CONTRACTOR
Currant & Layout Tunnels Strawberry Aqueduct, Heber City, Utah	U.S. Bureau of Reclamation Denver, Colorado	10'-4" Dia.	Combined Length 4.9 mi	S.A. Healy

A Robbins boring machine has been operating in sandstone. Existing logs of 13 drill holes show lithology. Compressive strength test results, varying from 5,000 psi for a shale to over 38,000 psi in the conglomerate, have been provided by the Bureau of Reclamation. This tunneling was stopped in September 1971 pending provision of additional funds but has since been resumed.

Rock Data:

Lithology: Sedimentary, sandstone, medium grained, light brown to red, massive, porous, poorly cemented.

Uniaxial Compressive Strength: 10 kpsi

RQD: (Estimated) 84%

Dry Unit Weight: 150 lb/ft^3

Ground Water: Generally dry.

Hardness: NA 1/11/72

Tunnel Data:

Size: 12 ft, 11 in. diameter. Grade: (+) .125%

Ventilation System: 15-17 kcfm exhaust, 36 in. dia. pipe, 100 hp at 4100 ft

Utility System: 3 1/2 in. water line, 6 in. air line, 8 in. pump line.

Water Inflow: 20-100 gpm

Power System: 7300/480 V

Haulage System: Muck, supplies, personnel, 10 ton locomotives, 6 2/3 CY cars, 24 in. gauge, 65 lb rail.

Support System: 4 in. H full rings, 4 ft centers: 35%; 13 in. × 9 ft pans 3/4 in. × 7 ft rock bolts: 10%.

Excavation Data:

Machine: Robbins 141-127, total weight: 125 tons

Cutters: 30 Robbins steel disc. Gauge: 6-11 in. Center: 1-11 in. triple disc. Interior: 23-11 in.

Rotation: Center cutter integral with head, 6 or 3 rpm

Torque: 600 hp

Thrust: 900 K# max., 685 K.# operating. Anchor pressure: 1,000 K#

Muck Collection: Pickup by buckets fixed to head, discharging on 30 in. belt to a 24 in. × 204 ft belt on gantry.

Power System: 6-480/240 V electric motors drive head. Hydraulic pumps power thrust and gripper cylinders.

Guidance System: Laser

Muck Data (Table V-1; Fig. V-2):

Abrasiveness: N.A. 1/11/72

Pot. Vol. Change, Material Size - 0.056 in.: 0

Spec. Gravity, Material Size -0.75 in.: 2.66

Atterbfrg Limits, Material Size (-)0.056 in.

Liquid Limit 21.20%	Plastic Limit 17.06%	Shrinkage Limit 15.17%
Plasticity Index 3.14%	Toughness Index 0.52	Flow Index 6.00

Material Size (-)2.0 in.

Angle/Repose 1 in. Drop @ 3.6% Moisture, 37°	Apparent Cohesion lb/ft^3 @ 3.6% Moisture, 210	Angle/Repose 10 in. Drop @ 3.6% Moisture, 35°
Angle Slide Steel Plate @ 3.6% Moisture, 27°	Bulk Density lb/ft^3 @ 0.0% Moisture, 97.4	Angle Internal Friction @ 3.6% Moisture, 38°

TABLE V-1

LAYOUT TUNNEL MUCK DATA

KEY	IDENTIFICATION	ROCK PROPERTIES	DRY WT PCF	COMPR STRNTH KPSI	RQD PCT EST	HARDNESS SHORE	HARDNESS MOH	HARDNESS SCHMIDT
25	LAYOUT SAMPLE NO LAY-1	SEDIMENTARY: SANDSTONE MEDIUM GRAINED. LIGHT BROWN TO RED. MASSIVE. POROUS. POORLY CEMENTED.	150	10	84	NA	NA	NA

MUCK DATA

DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 IN.SIZE	6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50	NO100	NO200	PCT (-) NO200
			PER CENT BY WEIGHT BETWEEN SCREENS												
105	4.1	0.0	7.6	7.5	5.7	12.0	12.6	4.6	3.4	2.7	1.8	15.4	1.0		25.7

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

6IN.	3IN.	2IN.	1IN.	1/2IN.	NO4	NO8	NO16	NO30	NO50
PI	PI	PI	PI	A	A	A	A	A	A

POT VOL CHANGE (-)0.056 IN.SIZE	ATTERBERG LIMITS..SIZE(-) 0.056IN. LIQUID LIMITS PCT	PLASTIC LIMIT PCT	SHRINKAGE LIMIT PCT	PLASTICITY INDEX PCT	FLOW INDEX	TOUGHNESS INDEX
0	21.20	17.06	15.17	3.14	6.00	0.52

(-)0.75 IN.SIZE SPECIF GRAVITY	MATERIAL SIZE(-)2.0 IN. ANGLE/REPOSE 1 IN DROP DEGREES AT 3.6 PCT MOIST	ANGLE/REPOSE 10 IN DROP DEGREES AT 3.6 PCT MOIST	ANGLE/SLIDE STEEL PLATE DEGREES AT 3.6 PCT MOIST	APPARENT COHESION PSF AT 3.6 PCT MOIST	BULK DENSITY PCF AT 0.0 PCT MOIST	SIZE(-)2.0 IN. ANGLE INTER FRICTION DEGREES AT 3.6 PCT MOIST
2.66	37	35	27	210	97.4	38

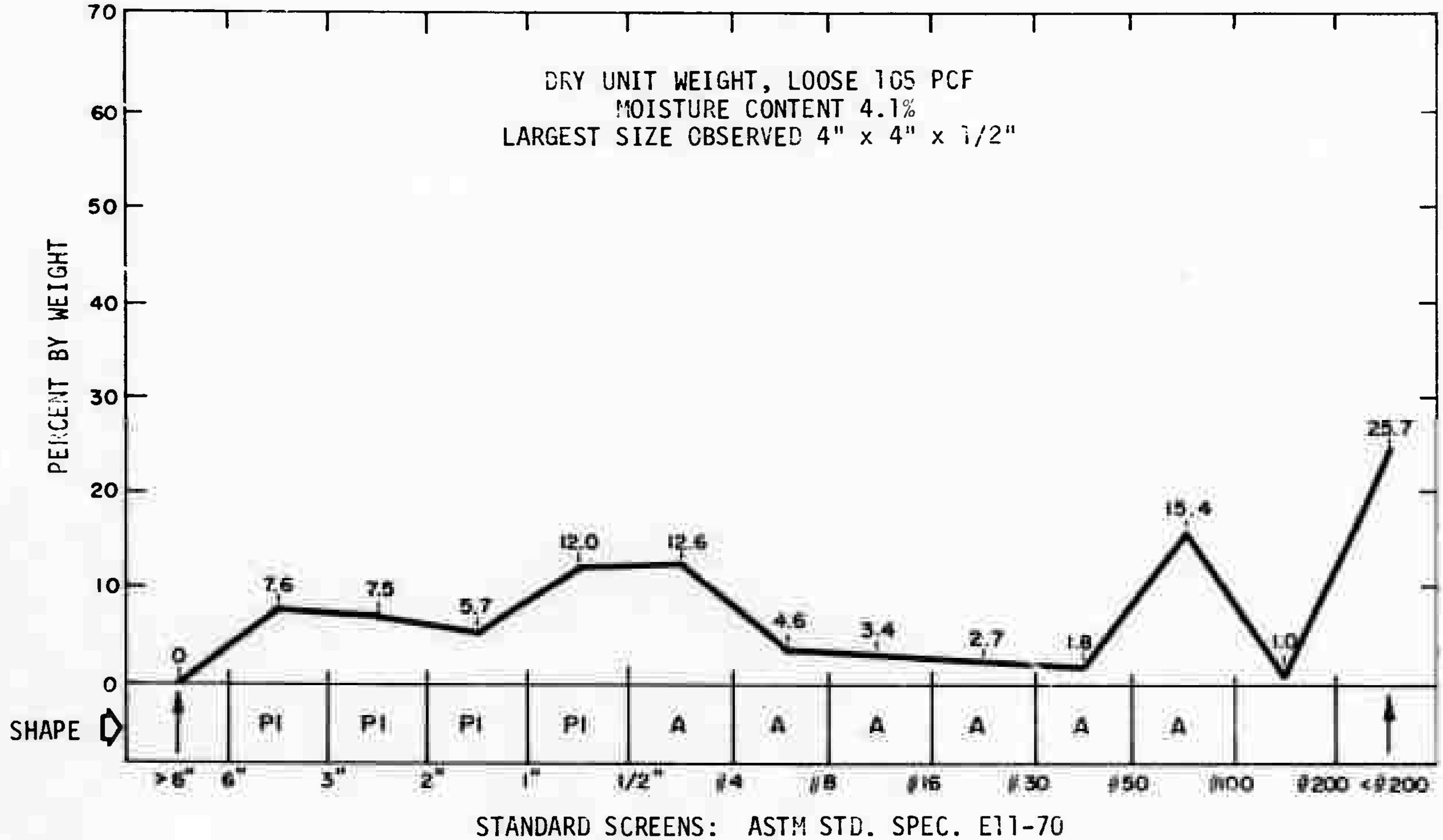


Figure V-2. Layout Tunnel Muck Characteristics

III. PROGRESS REPORTS

The following information is taken from the Bureau of Reclamation L-29 progress reports for the Layout Tunnel.

April 1971

Strawberry Aqueduct, Currant and Layout Tunnels, Diversions and Appurtenant Structures - Specifications No. DC-6855. Contract No. 41-06-D-7058. S. A. Healy Company.

At the close of the month, the percentage of work complete was:

	Part 1	Part 2
This month	0%	1%
To date	0%	1%
Time elapsed	47%	12%

Excavation for outlet portal Layout Tunnel was initiated April 27. The portal excavation of 6,414 yd^3 was completed during the month. The contractor plans to excavate 40 ft of tunnel from the outlet portal by conventional methods and the remainder of the tunnel with a mole.

The mole is scheduled for shipping from Robbins Plant in Seattle, Washington, about May 15.

The contractor continued with preparatory work for the camp site completion of developing two culinary water wells and completion of two sediment ponds. One well is located at the contractor's camp site and the other is near the outlet portal of Layout Tunnel. Well water samples were submitted to the State Health Department for tests. The sediment ponds are located downstream from the Water Hollow siphon.

L. G. Everst, Inc., will process sand and aggregate for concrete. Plans are to obtain the aggregate from a deposit owned by Elmer Ray Moon and located in SW1/4, Sec. 1, T.35, R.10W, Uinta Meridian.

All remaining work under Schedule 4 was subcontracted to Jerico-Highland of Murray, Utah. Jerico-Highland plans to excavate the inlet portal and the outlet portal for Layout and Currant Tunnels, respectively, during this summer. The subcontractor also plans to start work on the Water Hollow Diversion works and Layout Creek Access Road about the middle of May.

Contract earnings for the month and earnings to date are $128,280.00.

May 1971

Currant and Layout Tunnels - S. A. Healy Company excavated, by conventional methods, 54 ft of Layout Tunnel from the outlet portal. The Robbins mole arrived at the work site May 24. Offloading and assembly were started May 25. The access roads and tunnel portals in Layout Creek were cleared.

Strawberry Aqueduct, Currant and Layout Tunnels, Diversions and Appurtenant Structures - Specifications No. DC-6855. Contract No. 14-06-D-7058. S. A. Healy Company.

At the close of the month, the percentage of work complete was:

	Part 1	Part 2
This month	0%	0.3%
To date	0%	1.3%
Time elapsed	56%	14%

S. A. Healy Company excavated 54 ft of Layout Tunnel from the outlet portal by conventional methods in parparation for excavation with a mole. Water and air pipelines were installed to the portal.

The Robbins mole arrived at the work site May 24, and assembly was initiated May 25.

Jerico-Highland, subcontractor, initiated work on a bypass channel at the Water Hollow Diversion Dam.

Hamilton and Skewes, subcontractor for Jerico-Highland, cleared trees and brush from the Layout Creek road, Layout Creek road extension, Layout Tunnel inlet portal, Currant Tunnel outlet portal, Water Hollow Creek road extension, and Water Hollow Diversion Damsite. About half of the Water Hollow feeder pipeline right-of-way was also cleared.

Preparatory work by the prime and subcontractors included fabrication and ventilation of line and laying tracks.

The contractor plans to complete assembling the mole and start tunnel excavation by mole during June.

Jerico-Highland plans to complete the clearing operation and in early June to start building the Layout Creek Access Road and Water Hollow Diversion Dam.

Contract earnings for May were $14,202.00. Earnings to date are $142,482.00.

<u>June 1971</u>

Currant and Layout Tunnels - S. A. Healy initiated moling Layout Tunnel June 25 and moled 100 ft during the month. Jerico Construction excavated for Water Hollow Diversion Dam, completed open cut excavation of inlet portals of Currant Tunnel and Layout Tunnel, cleared Water Hollow Feeder Pipeline, and cleared and initiated construction of Layout Creek Access Road and Extension.

Strawberry Aqueduct, Currant and Layout Tunnels, Diversions and Appurtenant Structures - Specifications No. DC-6855. Contract No. 14-06-D-7058. S. A. Healy Company.

At the close of the month, the percentage of work complete was:

	Part 1	Part 2
This month	17%	1.7%
To date	17%	3%
Time elapsed	64%	16%

S. A. Healy Company excavated 100 ft of Layout Tunnel from near the outlet portal with a mechanical mole. Moling was initiated June 25, 1971.

Excavation was in hard sandstone and no support was required. Daily tunneling operations are as follows:

Date	Hours Operated	FOOTAGE Day	FOOTAGE Accumulated	Remarks
6/24/71				Station 1786+26.
6/25/71	3.9	6	6	Initial exc. by mechanical mole. Had difficulty controlling line and grade caused by grippers against unstable timbers in ribs.
6/28/71	5.3	27	33	Had electrical and gripper trouble.
6/29/71	3.3	32	65	Had an oil leak at the head of the mole and electrical trouble.
6/30/71	3.0	35	100	Moling resumed middle of swing shift without determining cause of oil leak.
Totals	15.5	100		Station 1785+26.

SUMMARY

Item	This Month	Previous	Total
Total operating time in hours	15.5	0	15.5
Total footage	100	0	100
Rate per hour	6.5	0	6.5
Maximum advance per day	35	0	35

Jerico Construction Company, subcontractor, completed excavating a bypass channel and excavated about 80% of the required foundation for Water Hollow Diversion Dam. Work on foundation excavation was slow as the dewatering system was inadequate until the third sump and pump were installed June 24, 1971. Open cut excavation for Layout Tunnel inlet and Currant Tunnel inlet was completed. Pioneering and excavating for Layout Creek Access Road and Layout Creek Access Road extension were initiated.

Hamilton and Skewes, subcontractor for Jerico Construction Company, finished the clearing.

Additional preparatory work by the prime and subcontractors included fabrication of ventilation line and laying tracks.

The contractor plans to excavate by mole on a 3-shift 5-days per week schedule. Plans are to excavate about 40 ft by conventional method from the inlet portal of Layout Tunnel.

Jerico Construction Company plans to work on building the Layout Creek Access Road, Layout Creek Access Road Extension, Water Hollow Diversion Dam earthwork and concrete, and the excavation at the Currant Tunnel outlet portal.

Contract earnings for June were $202,988.00. Earnings to date are $345,470.00.

July 1971

Strawberry Aqueduct, Currant and Layout Tunnels, Diversions and Appurtenant Structures - Specifications No. DC-6855. Contract No. 14-06-D-7058. S. A. Healy Company.

At the close of the month, the percentage of work complete was:

	Part 1	Part 2
This month	2%	5%
To date	19%	8%
Time elapsed	73%	18%

S. A. Healy Company excavated 1,329 ft of Layout Tunnel from Station 1785+26 to Station 1771+97 with a mechanical mole. From Station 1774+71 to 1772+40, some fallout and water were encountered. Through this reach, structural steel supports with lagging was installed and timber was used for gripper pads.

Ground formations consisted of hard and softer layers of sandstone with some gravel and conglomerate seams.

Daily tunneling operations are as follows:

Date	Hours Operated	FOOTAGE Day	FOOTAGE Accumulated	Remarks
6/30/71			100	Station 1785+26
7/1/71	5.9	71	171	Electric drive motor for hydraulic pumps that run gantry belt failed. Stopped moling, worked to install fanline, tracks, and maintain cat-walk and gantry.

FOOTAGE (Cont.)

Date	Hours Operated	Day	Accumulated	Remarks
7/2/71	4.1	62	233	Changes two cutters, Nos. 10 and 23. Motor was removed graveyard shift. Replaced with new motor during swing shift. High speed RPM cut out drive motors. Used low speed RPM.
7/3/71	3.8	52	285	Material increasing in hardness.
7/6/71	4.5	50	335	Changed three cutters, Nos. 27, 28, and 29, slight fault, 3 in. by 4 ft in crown section well cemented. (No supports required this day.)
7/7/71	12.8	158	493	Changed two cutters, Nos. 1 and 23. Hit small flow of water at left rib, Sta. 1783+76. Belt trouble, shut down from 3:45 p.m. to 4:30 and 30 min during swing shift.
7/8/71	10.6	129	622	(Routine working conditions.) Electrical trouble with 100 hp drive motors. Change three cutters, Nos. 16, 28, and 29.
7/9/71	11.1	161	783	Changed 17 cutters, Nos. 2, 3, 4, 5, 6, 8, 9, 10, 11, 27, 12, 14, 15, 25, 28, and 29. Down because of trouble with trains in disposal area and to check outer seal.
7/10/71	4.4	54	837	Started changing cutters.
7/12/71	5.4	70	907	Changed two cutters, Nos. 12 and 29. Had trouble with pump on scrubber and mole belt. Down to check noisey cutter, and installing spray bar at gantry belt pickup from mole belt.
7/13/71	8.3	96	1003	Changed three cutters, Nos. 17, 22, and 23. Down to revamp spray nozzle bar between mole belt and gantry belt. One train of loaded muck cars derailed at 5:00 a.m. Mole belt plugged and slipped from wet material.

FOOTAGE (Cont.)

Date	Hours Operated	Day	Accumulated	Remarks
7/14/71	8.8	106	1109	Changed seven cutters, Nos. 13, 23, 25, 26, 27, 28 and 29. Had belt problems. Tried new spray bar. Down with broken hydraulic line to mole conveyor.
7/15/71	7.1	85	1194	Excavated 61 ft on graveyard shift. Hit bad ground, sand and gravel washed out with approximately 15 gpm flow of water. Started rib steel supports and lagging as mole advanced. Cribbing behind grippers was necessary in places.
7/16/71	3.6	31	1225	Had trouble gripping and with chunks falling out from above springline.
7/17/71	0.3	3	1228	Cleaned out invert of tunnel. Advanced mole 3 ft when another large fallout from crown occurred. Placed rib support steel.
7/19/71	1.7	14	1242	Changed cutter No. 27. Installed ribs at 3-ft centers and lagged and moled intermittently.
7/20/71	3.8	14	1256	Had trouble with grippers against unstable lagging.
7/21/71	5.2	46	1302	Had trouble with transformer and left side gripper moving rib steel and lagging.
7/22/71	2.6	31	1333	Day shift 7/22 thru graveyard shift 7/26 were spent on mole, airline maintenance and structural steel supporting of bad ground.
7/26/71	4.1	43	1376	Ran mole enough for one set of support steel at a time until mole was stopped due to dust after waterline to scrubber was broken.
7/27/71	5.3	53	1429	Changed seven cutters, Nos. 23, 13, 16, 12, 15, 29, and 26. Installed gantry.
Month Total	113.4	1329		Station 1771+97

SUMMARY

Item	This Month	Previous	Total
Total operating time in hours	113.4	15.5	128.9
Total footage	1,329	100	1,429
Rate per hour	11.7	6.5	11.1
Maximum advance per day	161	35	-----

Structural steel tunnel supports consisting of 4" H beam 13#/ft were installed as follows:

Stations:	
1774+71 to 1774+63	Partial ring set on 4 ft centers and pinned 2 ft below springline.
1774+59 to 1774+47	Full ring on 4 ft centers.
1774+43 to 1774+23	Partial ring set on 4 ft centers and pinned 2 ft below springline.
1774+19 to 1774+15	Full ring on 4 ft centers.
1774+15 to 1774+08	Full ring on 3 ft centers.
1774+08 to 1773+98	Full ring on 2 ft centers.
1773+98 to 1772+64	Full ring on 4 ft centers.
1772+60 to 1772+40	Partial ring set on 4 ft centers and pinned at springline.

Jerico Contruction Company, subcontractor, excavated the foundation for Water Hollow Diversion Dam and started compacted embankment. Work on foundation excavation and embankment was slow as the contractor had difficulty with dewatering. Initial concrete placement was made for the footing of the upstream cutoff wall for Water Hollow Diversion Dam. Undesirable material was removed and backfill and compacted backfill for structures were placed for the Water Hollow Tunnel intake structure. Open cut excavation for tunnel portals was substantially completed. Excavating for Layout Creek Access Road and Layout Creek Access Road Extension advanced to about 55%.

The contractor plans to excavate by mole on a 3-shift 5-days per week schedule. Plans are to excavate about 40 ft by conventional method from the inlet portal of Layout Tunnel.

Contract earnings for July were $612,231.00. Earnings to date are $957,701.00.

August 1971

Strawberry Aqueduct, Currant and Layout Tunnels, Diversions and Appurtenant Structures - Specifications No. DC-6855. Contract No. 14-06-D-7058. S. A. Healy Company.

At the close of the month, the percentage of work complete was:

	Part 1	Part 2
This month	18%	8%
To date	37%	16%
Time elapsed	82%	20%

S. A. Healy Company excavated 2,314 ft of Layout Tunnel from Station 1771+97 to Station 1748+83 with the mechanical mole.

Ground formations consisted of hard and soft layers of sandstone with some siltstone, conglomerate and shale seams. Supports were required in the following areas:

1767+38 to 1761+94
1759+22 to 1759+06
1758+04 to 1756+17
1752+62 to 1748+83

Through these reaches, steel pans with rock bolts or structural steel supports with lagging and cribbing were installed. Timber was used for gripper pads as needed.

Daily tunneling operations are as follows:

Date	Hours Operated	FOOTAGE Day	FOOTAGE Accumulated	Remarks
7/31/71				Station 1771+97
8/2/71	5.2	83	1,512	Hydraulic system repaired, some ground water encountered.
8/3/71	9.6	130	1,642	Changed 16 cutters, Nos. 22, 11, 7, 18, 10, 19, 28, 14, 20, 15, 23, 23, 23, 7, 8, and 9. No. 7 cutter was changed twice, once on day shift and once following graveyard shift; and No. 23 was changed three times on swing shift, when material was hardest.
8/4/71	6.9	118	1,760	Changed 11 cutters, Nos. 24, 25, 26, 28, 6, 3, 16, 21, 15, 28, and 29. Cutter No. 28 changed twice.
8/5/71	6.0	82	1,842	Changed 6 cutters, Nos. 19, 12, 18, 13, 21, and 20. Down day shift waiting on repair parts. No moling 9:30 p.m. to 10:00 p.m. while unsafe conditions were being corrected. Rockbolts with pans were tried as support on left side, between Stations 1769+75 and 1769+90, but 6 ft rockbolts failed to torque.
8/6/71	9.1	106	1,948	Changed 18 cutters, Nos. 23, 14, 27, 11, 17, 5, and 24, 23, 24, 25, 26, 27, 29, 10, 21, 15, 3, and 29. Cutters changed twice at locations No. 23, 27, 24, and 29. Grippers fractured material causing flaking from left side. 10' × 12" × 16 gage pans were anchored with 2 ft rock bolts from Station 1767+04 to 1766+84.
8/7/71	0	0	1,948	Changed center cutter.

FOOTAGE (Cont.)

Date	Hours Operated	Day	Accumulated	Remarks
8/9/71	12.9	155	2,103	Changed cutter No. 23. Had trouble gripping on sides. Pans and rockbolts used from Stations 1766+84 to 1765+86.
8/10/71	2.4	25	2,128	Hit soft, wet, caving ground; water inflow estimated at 70 to 80 gpm. Placed structural steel supports and lagging intermittently.
8/11/71	3.8	36	2,164	Set structural steel supports and lagging.
8/12/71	5.4	47	2,211	Conditions similar to those encountered 10th and 11th except estimated 100 gpm of water.
8/13/71	7.6	86	2,297	Moled, blocked grippers, placed support steel and lagging intermittently and pumped water. Had trouble with mud building up around support wheels for transformer and scrubber platform.
8/14/71	0	0	2,297	Changed 4 cutters, Nos. 1, 15, 26, and 29.
8/16/71	8.3	97	2,394	Changed 5 cutters, Nos. 26, 11, 28, 18, and 16. Ground became firmer.
8/17/71	7.6	99	2,493	Changed 7 cutters, Nos. 26, 18, 10, 19, 21, 23, and 25. Placed support steel and lagging, heading became dry and supports were discontinued.
8/18/71	15.4	209	2,703	Changed 6 cutters, Nos. 24, 28, 22, 7, 14, and 2. The hydraulic "tugger" system for moving muck cars under the gantry was tried. It was slow and could move only 8 cars at a time when loading. Started supporting with rockbolts and pans at Station 1759+90. Empty muck car derailed at 7:30 p.m.

FOOTAGE (Cont.)

Date	Hours Operated	Day	Accumulated	Remarks
8/19/71	13.5	194	2,896	Changed 11 cutters, Nos. 29, 6, 16, 21, 22, 2, 11, 17, 23, 19, and 10. Contractor worked to correct cause of derailment from 8 to 10:40 a.m. and started moling at 10:40. Maximum advance was 4¼ in. per min with 2100 lb of propel. Water was encountered above invert on left side at Station 1758+01.
8/20/71	4.4	59	2,955	Changed cutter No. 24. Down 3 hr and 10 min on day shift to set transformer at Station 1768+36 and install 1,000 ft of 7200 volt electric cable. At 3:15 p.m., encountered loose conglomerate which required steel rib supports, moled 4 ft at a time then stopped to place support steel and lagging.
8/21/71	0	0	2,955	Changed 6 cutters, Nos. 5, 11, 17, 23, 25, and 28.
8/23/71	9.4	86	3,041	Changed 7 cutters; Nos. 24, 27, 9, 6, 14, 18 and 22. Continued to mole slowly and installed supports for most of day. Down an hour to repair vent line and scrubber. Material got harder and had more stability.
8/24/71	16.4	150	3,191	Changed 16 cutters, Nos. 1, 29, 15, 18, 12, 10, 16, 11, 12, 13, 19, 17, 22, 23, 8 and 3. Cutter at location No. 12 was changed twice. Down twice on swing shift and once on graveyard shift to change cutters because of hard well cemented conglomerate. Advanced 2 in. per min at propel pressure of 2,800 psi.

FOOTAGE (Cont.)

Date	Hours Operated	Day	Accumulated	Remarks
8/25/71	15.6	172	3,363	Changed 23 cutters, Nos. 15, 16, 20, 18, 14, 22, 19, 25, 24, 26, 28, 27, 29, 22, 21, 7, 17, 23, 13, 24, 21, 11, and 16. Cutters at locations Nos. 16, 21, 22, and 24 were changed twice.
8/26/71	6.5	60	3,423	Water encountered in crown at 3:00 p.m. Started setting pans and rockbolts. Changed water nozzles at throat of the mole for better dust control. At 4:15 p.m. began installing structural steel supports.
8/27/71	11.6	107	3,530	Changed 3 cutters, Nos. 4, 28, 29. Moled and set steel alternately until shut down for hydraulic system repairs.
8/28/71	0	0	3,530	Changed 5 cutters, Nos. 14, 19, 23, 25, and 27, and set some structural steel supports while making hydraulic system repairs.
8/30/71	9.2	100	3,630	Changed 2 cutters, Nos. 12 and 20. Continued repair on hydraulic system and encountered ground that required supports.
8/31/71	7.5	113	3,743	Changed 2 cutters, Nos. 28 and 29. Moled 4 ft and set support steel alternately.
8/31/71				Station 1748+83.

SUMMARY

Item	This Month	Previous	Total
Total operating time in hours	194.3	128.9	323.2
Total footage	2,314	1,429	3,743
Rate per hour	11.9	11.1	11.6
Maximum advance per day	209	161	-----

Jerico Construction Company, subcontractor, placed approximately 25% of the compacted embankment and compacted backfill for Water Hollow Diversion Dam. This material came from borrow. Nearly all of the structural excavation in the diversion dam was oversize and rejected.

About 102 yd^3 of concrete was placed for the upstream cutoff wall, cutoff walls under the spillway and sluiceway floors, and the 10' × 31' × 4' sluiceway floor section. At the Water Hollow Tunnel inlet structure, 19 yd^3 concrete was placed for the floor and part of the walls.

Excavation and embankments for Layout Creek Access Road, Layout Creek Access Road Extension and Road above the Layout Feeder Pipeline were substantially completed. Earthwork and laying of pipe were initiated for the Layout Feeder Pipeline.

Jerico Construction Company plans to work a 10-hr shift 6 days per week on Water Hollow diversion structures. L. G. Everst plans to process coarse concrete aggregate until winter shutdown about October 1, 1971. Plans are to use a rod-mill next summer to process sand for concrete because current processes have failed to produce sand within the specified gradation.

Contract earnings for August were $708,358.60. Earnings to date are $1,666,059.60.

September 1971

Currant and Layout Tunnels - S. A. Healy moled 1,295 ft of Layout Tunnel. On September 22, the contractor discontinued moling because funds were exhausted. About 2,900 ft of pipe was laid for Layout Feeder Pipeline and 235 yd^3 of concrete was placed for Water Hollow Diversion Dam and the inlet structure to Water Hollow Tunnel.

Strawberry Aqueduct, Currant and Layout Tunnels, Diversions and Appurtenant Structures - Specifications No. DC-6855. Contract No. 14-06-D-7058. S. A. Healy Company.

At the close of the month, the percentage of work complete was:

	Part 1	Part 2
This month	22%	6%
To date	59%	22%
Time elapsed	91%	22%

S. A. Healy Company excavated 1,295 ft of Layout Tunnel from Station 1748+83 to 1735+88 with the mechanical mole.

On September 22, at noon, the contractor discontinued tunnel excavation because funds were exhausted. Swing and graveyard shifts were discontinued on September 24 and 25 respectively. By September 30, S. A. Healy had laid off all employees except supervisory personnel.

The material at the heading when work was discontinued is conglomerate in the arch to about 2 ft above springline and shale and sandstone below that.

The contractor has completed the following work to protect the Layout Tunnel and boring machine during the shut down period:

1. Applied shotcrete to 90% of the tunnel except for the invert from the end of the California switch to and including the heading.
2. Installed 4 in. tunnel support steel on 4 ft centers around the mole.
3. Installed a bulkhead at the outlet portal.

4. Installed 8 in. drain pipe at the outlet portal. This line connected to the invert of the tunnel to the original 8 in. pump discharge line outside the portal and was buried about 2 ft. The pipe was insulated when buried.

5. Cleaned invert of tunnel around mole and backup equipment to facilitate drainage of water. Pumping was discontinued October 1, 1971.

6. Performed general cleanup of the mole and backup equipment.

7. Blocked up the mole and retracted all hydraulic rams.

8. Greased all machine surfaces left exposed.

9. Activated internal heaters in the electric drive motors on the mole head.

10. Electricians sprayed a moisture proof preservative coating on all internal electrical wiring for motors, transformers, switches, etc.

11. Covered mole with a plastic covering.

In addition, the contractor plans to have watchmen on the job site during the entire shut down period. Also, electric power will be left on in the tunnel to activate the motor heaters and keep the transformers in operation to prevent deterioration.

Ground formations excavated during the month consisted of hard and soft layers of sandstone with some siltstone, conglomerate and shale seams. Structural steel supports with cribbing and lagging were installed in the following areas:

1748+83 to 1743+42
1740+64 to 1738+80
1736+32 to 1736+00

Timber was used for gripper pads as needed. A small amount of pans with rock bolts were also installed.

Approximately 170 yd^3 of shotcrete was placed to retard rock deterioration along the tunnel walls and crown between Stations 1784+50 and 1735+88 on an intermittent basis as needed.

Daily tunneling operations were as follows:

Date	Hours Operated	FOOTAGE Day	FOOTAGE Accumulated	Remarks
8/31/71			3,743	Station 1748+83
9/1/71	5.3	86	3,829	Changed 9 cutters, Nos. 25, 29, 18, 24, 27, 26, 21, 15, and 9. Alternately moled 4 ft and stopped to set rib support steel at 4 ft centers. Grippers cause rock to slab off.
9/2/71	8.8	123	3,952	Changed 10 cutters, Nos. 23, 17, 20, 8, 19, 22, 16, 10, 28, and 29. Alternately moled 4 ft and stopped to set rib support steel. Material was getting more stable.
9/3/71	9.4	126	4,078	Changed 7 cutters, Nos. 14, 13, 8, 6, 5, 11, and 23. Alternately moled 4 ft and stopped to set rib support steel. Material was getting softer and falling out from both sides.
9/7/71	5.2	71	4,149	Changed 2 cutters, Nos. 23 and 28. Alternately moled 4 ft and stopped to set rib support steel. Ground was blockey and some slabs fell out.
9/8/71	6.2	93	4,242	Changed 5 cutters, Nos. 27, 21, 18, 15, and 2. Alternately moled 4 ft and stopped to set rib support steel, as grippers were breaking slabs out.

FOOTAGE (Cont.)

Date	Hours Operated	Day	Accumulated	Remarks
9/9/71	5.6	66	4,308	Changed 13 cutters, Nos. 29, 26, 27, 12, 23, 22, 28, 24, 23, 26, 25, 27, and 29. Cutters at location No. 23, 26, 27, and 29 were changed twice. Alternately moled 4 ft and stopped to set steel until rib support steel was discontinued at Station 1743+42± at stable ground.
9/10/71	6.1	60	4,368	Changed 5 cutters, Nos. 17, 20, 21, 24, and 26. Ground was harder and moling speed was slow.
9/13/71	11.5	92	4,460	Changed 14 cutters, Nos. 14, 15, 16, 23, 11, 9, 4, 8, 13, 19, 20, 21, 10 and 2. Had trouble with high speed gripper valve, dust control equipment and conveyor belts. Stopped from time to time to repair these.
9/14/71	12.1	104	4,564	Changed 14 cutters, Nos. 5, 7, 10, 17, 18, 23, 24, 25, 26, 27, 28, 29, 1, and the center cutter. Hose to spray bar, dust controller, replaced.
9/15/71	5.4	69	4,633	Changed 2 cutters, Nos. 22 and 23. Moled 4 ft and stopped to install full ring steel supports alternately. Also had trouble getting grippers to hold.
9/16/71	8.5	79	4,712	Alternately moled 4 ft and stopped to set full ring support steel. Lagging behind grippers was required.
9/17/71	10.4	84	4,796	Changed 3 cutters, Nos. 23, twice and 24 once. Alternately moled 4 ft and stopped to set full ring support steel. At Station 1738+80, rib support steel was discontinued.

FOOTAGE (Cont.)

Date	Hours Operated	Day	Accumulated	Remarks
9/20/71	7.0	85	4,881	Changed 14 cutters, Nos. 8, 10, 11, 15, 16, 17, 18, 19, 21, 22, 24, 26, 28, and 29. The lubricating system to the cutter head bearings was repaired.
9/21/71	11.9	140	5,021	Changed 10 cutters, Nos. 14, 20, 23, 24, 25, 27, 3, 6, 8, and 29. Mole was without power for about 7 hr while contractor installed new transformer.
9/22/71	1.6	17	5,038	When softer ground was first encountered at 11:30 a.m., the contractor elected to stop the mole to leave it in stable ground until additional funds are available.
9/30/71				Station 1735+88

SUMMARY

Item	This Month	Previous	Total
Total operating time in hours	115.0	323.2	438.2
Total footage	1,295	3,743	5,038
Rate per hour	11.3	11.6	11.5
Maximum advance per day	140	209	

Jerico Construction Company, subcontractor, is working one 10-hr shift six days per week. About 207 yd^3 of concrete was placed for the upstream middle apron, right and left wing walls, left downstream cutoff wall and the remaining spillway floor for Water Hollow Diversion Dam. At the Water Hollow Tunnel inlet structure, about 28 yd^3 of concrete was placed for the upper parts of the walls and roof sections.

Earthwork and laying of pipe for the Layout Feeder Pipeline were advanced about 2,900 ft.

L. G. Everest, subcontractor, discontinued processing concrete aggregates until after the winter months. Some fine sand was produced and blended with the coarse sand already produced to obtain sand within specified gradations. This sand was used for shotcrete material in Layout Tunnel.

Contract earnings for September were $695,912.32. Earnings to date are $2,361,971.92.

IV. WAGE RATE SPECIFICATIONS: CENTRAL UTAH, 1970-1971

This information is taken from the Schedule, General Provisions, Specification, and Drawings, Strawberry Aqueduct, Currant and Layout Tunnels, Specifications No. DC-6855, U.S. Department of Interior, Bureau of Reclamation.

Pursuant to the provisions of the Davis-Bacon Act, 40 U S C. 276(a), as amended, the Secretary of Labor has determined that rates of wages and fringe benefits listed in this paragraph are those prevailing for the classifications specified in the locality of the work covered by these specifications and said rates of wages and fringe benefits shall be the minimum rates per hour to be paid for the work covered by the specifications.

Fringe benefit payments include medical and hospital care, compensation for injuries or illness resulting from occupational activity, unemployment benefits, life insurance, disability and sickness insurance, accident insurance (all designated as health and welfare), pensions, vacation and holiday pay, apprenticeship, or other similar programs, and other bona fide fringe benefits.

While the wage rates and fringe benefits shown are the minimum rates required by these specifications to be paid during the life of the contract, it is the responsibility of bidders to inform themselves as to local labor conditions such as the length of workday or workweek, overtime compensation, fringe benefit contributions, labor supply, and prospective changes or adjustments of wage rates or fringe benefits. No increase in the contract price will be allowed or authorized on account of the payment of wage rates or fringe benefits in excess of those listed herein.

Decision No. AK-2,013 (3) dated 8-16-70

	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP TR	OTHERS
ASBESTOS WORKERS	6.81	.35	.42			
BOILERMAKERS	6.30	.30	.55	.40	.02	
BOILERMAKERS' HELPERS	6.00	.30	.55	.40	.02	
BRICKLAYERS	5.86	.21	.15			
CARPENTERS:						
Carpenters:						
Zone 1: (40 miles or less from Brigham City-Cedar City-Kanab-Logan-Ogden-Price-Provo-Richfield-Salt Lake City-Vernal)	6.30	.15	.20	.13	.02	
Zone 2: (Beyond 40 thru 50 miles from Brigham City-Cedar City-Kanab-Logan-Ogden-Price-Provo-Richfield-Salt Lake City-Vernal)	7.05	.15	.20	.13	.02	
Zone 3: (Beyond 50 thru 60 miles from Brigham City-Cedar City-Kanab-Logan-Ogden-Price-Provo-Richfield-Salt Lake City-Vernal)	7.175	.15	.20	.13	.02	
Zone 4: (Over 60 miles from Brigham City-Cedar City-Kanab-Logan-Ogden-Price-Provo-Richfield-Salt Lake City-Vernal)	7.30	.15	.20	.13	.02	
Saw Filers, Saw Ops., & Carpenters handling creosote material:						
Zone 1	6.425	.15	.20	.13	.02	
Zone 2	7.175	.15	.20	.13	.02	
Zone 3	7.30	.15	.20	.13	.02	
Zone 4	7.425	.15	.20	.13	.02	
Millwrights (All Zones)	6.55	.15	.20	.13	.02	
Acoustical Carpenters (All Zones)	6.30	.15	.20	.13	.02	
CEMENT MASONS:						
Cement Masons						
Zone 1 (The area less than 45 miles from any county seat except Daggett County)	5.87	.15	.20	.13		
Zone 2 (All of DAGGETT COUNTY and the area beyond a distance greater than a radius of 45 miles from the remaining county seats)	6.27	.15	.20	.13		
Machine Op.; Mastic Floor Materials; Spark Proofing; Scaffold (20 to 40 ft.)						
Zone 1	6.00	.15	.20	.13		
Zone 2	6.40	.15	.20	.13		

Decision No. AK-2,013 (3)

	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS H & W	PENSIONS	VACATION	APP. TR.	OTHERS
DRYWALL INSTALLERS:						
Taping, finishing and texturing (hand or machine)	5.[illegible]5	.16	.12		.02	
ELECTRICIANS:						
Cache-Davis (That portion of Davis Co. lying north of the 41st parallel)-Weber Counties.						
Electricians	6.20	.18	1%		3/10%	
Cable Splicers	6.45	.18	1%		3/10%	
Box Elder-Morgan-Rich Counties.						
Electricians	7.20	.18	1%		3/10%	
Cable Splicers	7.45	.18	1%		3/10%	
Salt Lake County & that portion of Davis County lying south of the 41st parallel; and that portion of Utah County lying north of the 40th parallel.						
10 mi. East or West from Interstate Hwy #15:						
Electricians	6.20	.18	1%		8/10%	
Cable Splicers	6.45	.18	1%		8/10%	
Over 10 mi. East or West from Interstate Hwy #15:						
Electricians	6.70	.18	1%		8/10%	
Cable Splicers	6.95	.18	1%		8/10%	
Remainder of State.						
Electricians	7.70	.18	1%		8/10%	
Cable Splicers	7.95	.18	1%		8/10%	
ELEVATOR CONSTRUCTORS	5.56	.16	.185	2%+a		
ELEVATOR CONSTRUCTORS' HELPERS	70%JR	.16	.185	2%+a		
ELEVATOR CONSTRUCTORS' HELPERS (PROB.)	50%					
GLAZIERS	4.39	.16		b		
IRONWORKERS:						
Ornamental-Reinforcing-Fence Erector-Structural	6.475	.25	.25		.025	
LABORERS:						
Brick Tenders	4.65	.15	.25			
Plasterers' Tenders	5.195	.20	.25			
LATHERS	5.63	.20	.40		.01	
LEAD BURNERS	5.10	.15		c	.01	
LINE CONSTRUCTION:						
Cable Splicers	6.37	.15	1%		3/[illegible]%	
Linemen	5.81	.15	1%		3/[illegible]%	
Line Equipment Operator	5.15	.15	1%		3/[illegible]%	
Head Groundmen	4.47	.15	1%		3/[illegible]%	
Groundmen	4.05	.15	1%		3/[illegible]%	

	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP. TR	OTHERS
PAINTERS:						
Area North of 41st Parallel.						
Brush	4.50	.16			.01	
Spray; Structural Steel; Swing Stage	4.50	.16			.01	
Steeple Jack Work	4.50	.16			.01	
Remaining part of State.						
Brush; Roller; Paperhanger; Sheet Rock Taper	4.87	.16	.12		.01	
Brush (Swing Stage); Brush (Steel & Bridge); Spray & Sandblaster; Steeple Jack	5.07	.16	.12		.01	
Spray (Swing Stage); Spray (Steel & Bridge); Sandblaster (Swing Stage); and special Coating Applicator	5.27	.16	.12		.01	
PILEDRIVERMEN; Bridge, Wharf, & Dock Carpenters, Riggers, Boom Men	7.09	.15	.20	.13	.02	
PLASTERERS	5.86	.20	.20		.01	
PLUMBERS; Pipefitters & Steamfitters:						
Zone 1- 15 mi. radius from center of each city, namely Salt Lake City, Ogden and Provo	6.15	.16	.20		.04	
Zone 2- Zone 1 plus 15 miles	6.45	.16	.20		.04	
Zone 3- Zone 2 plus 15 miles	6.80	.16	.20		.04	
Zone 4- All areas beyond Zone 3.	7.65	.16	.20		.04	
REFRIGERATION & AIR CONDITIONING:						
50 tons or over:						
Zone 1- 15 mi. radius from center of each city, namely Salt Lake City, Ogden and Provo	6.45	.16	.20		.02	
Zone 2- Zone 1 plus 15 miles	6.80	.16	.20		.02	
Zone 3- Zone 2 plus 15 miles	7.15	.16	.20		.02	
Zone 4- All areas beyond Zone 3.	7.50	.16	.20		.02	
Under 50 tons:						
All Zones	5.35	.16			.02	
ROOFERS	5.55	.10	.10			
SHEET METAL WORKERS	5.70	.18	.20			
SPRINKLER FITTERS	6.20	.20	.30		.05	
TERRAZZO WORKERS	5.00					
TILE SETTERS	5.00					

WELDERS: Receive rate prescribed for craft to which welding is incidental.

FOOTNOTES:

a. Employer contributes 4% of basic hourly rate for 5 years' service and 2% basic hourly rate for 6 months to 5 years' service as Vacation Pay Credit. 6 Paid Holidays: A through F.

b. Employee shall receive 2 weeks' vacation with pay after completion of one year of service; Employee who has served continuously with one employer for twelve years to receive a third week's vacation. 7 Paid Holidays. A through F plus July 24th.

c. Eight paid holidays: A through F plus Washington's Birthday and Good Friday, providing employee has worked 45 full days during the 120 calendar days prior to the holiday, and the regular scheduled work days immediately preceding & following the holiday.

PAID HOLIDAYS:
A-New Year's Day; B-Memorial Day; C-Independance Day; D-Labor Day; E-Thanksgiving Day; F-Christmas Day.

Decision No. AK-2,013 (3)

That area in the State of Utah within 45 road miles of the county seats excluding Daggett County

LABORERS	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP. TR.	OTHERS
GROUP I						
Boxman, Carpenter tender, Cement finisher helper, Chat boxman, Choker setter, Clearing & grading, Cleaning of equipment & parts in connection with concrete, Concrete crew, Dock-hand & cleaning man, Fence erector & installer (includes installation & erection of fences, guard rails, median rails, reference post, guide post, & right-of-way markers), Flagmen, Form stripper, Gardener helper, General laborer, Grizzley operator (whether by power or hand), Group pump operators, Heaters tender, Helpers (all not herein seperately classified), House mover, Landscaping helper, Laborers on wrecking & Demolition, Nurseryman helper, Pre-waterman, Riprap man (hand placed), Sloper, Spreader & weighman, Stake jumper, Stripping & cleaning of steel & pans, Tool dispatcher & checker (full time), Unloading & packing of reinforcing steel rods & mesh	4.305	.15	.25		.04	
GROUP II						
Air track helper, Asphalt rakers & ironers, Dumpman, Gunite reboundman, Hand & chain saw operator (bucking & falling timber), J. Tamper & similar type tampers, Metal form setter (airport paving & highway) Operator & tenders of pneumatic & electric tools & compressors & concrete saw, Operators of power-type form cleaner & oiling machines, Pipe wrapper, Pot tender & joint maker, Power type buggies, Rollers, Screen & cleanup man, Signal & Dumpman on concrete construction, Tunnel & belt man,	4.43	.15	.25		.04	
GROUP III						
Barko vibratory roller & similar type, Compacting machines, High pressure water nozzleman, Jackhammer & pavement						

Decision No. AK-2,013 (3)

LABORERS-Cont'd	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP. TR.	OTHERS
GROUP III- Cont'd						
breaker, Pipelayer, Powderman helper, Pumpcrete operators, Refinery tank & vessel cleaners, Sand Blasters, Sand blaster pot tender, Vibrator operator, Work of all type using cutting torches & tools needed in wrecking	4.555	.15	.25		.04	
GROUP IV						
Air track & core diamond drillers, Drill mechanic (on job site), High acceler- operating jackhammer or breaker, Mailn vibrators & similar types - 70 lbs., Multiple side boom driller, Wagon driller	4.68	.15	.25		.04	
GROUP V						
Gunite groundman, gunite nozzleman, gunite rodman, Powderman	5.03	.15	.25		.04	
TUNNEL AND SHAFT WORK:						
GROUP I (Underground) Underground Laborers	4.43	.15	.25		.04	
GROUP II (Underground) Breakman, Chucktender, Dumpman, Powderman helper, Puddler	4.53	.15	.25		.04	
GROUP III (Underground) Nipper, Screedman, Vibrator, Tapman	*4.63	.15	.25		.04	
GROUP IV (Underground) Cutting machine operator, Drill doctor, Finisher, Gunite gunman, Miners, Powder make-up man, Speder & Tuggers, Steelman, Timberman	4.73	.15	.25		.04	
GROUP V (Underground) Gunite groundman, Gunite nozzleman, Gunite rodman	5.03	.15	.25		.04	
GROUP VI (Underground) Shifter	5.18	.15	.25		.04	

Decision No. AK-2,013 (3)

*AREA 1

POWER EQUIPMENT OPERATORS	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP. TR.	OTHERS
GROUP I Chainman; Rodman	4.69	.41	.45	.20	.05	
GROUP II Asphalt Plant Fireman; Brakeman-Locomotive; Elevator Operator; Fireman; Hydraulic Monitor; Material Loader or Conveyor Operator; Partsman - Field; Grade Setter - Repairman Helper - Field	5.09	.41	.45	.20	.05	
GROUP III Air Compressor Operator; Concrete Mixer Operator (skip type); Concrete Pump or Pumpcrete Gun Operator; Engineer, Dinkey Operator; Generator (100 KW or over); Mixer Box Operator (Concrete or Asphalt plant) (continuous mix or similar); Pump Operator; Self-propelled, Automatically applied concrete curing machine (on streets, highways, airports and canals); Screedman; Truck Crane Oiler	5.38	.41	.45	.20	.05	
GROUP IV Ballast Jack Tamper; Ballast Regulator; Ballast Tamper-Multiple Purpose; Front End Loader up to and including 1 c.y. Struck MRC; Hoist Operator - 1 Drum; Line Master; Lubrication & Service Engineer (Mobile & Grease Rack); Slip Form Pumps	5.51	.41	.45	.20	.05	
GROUP IV-A Heavy Duty Repairman and Welder Permanent Shop	5.59	.41	.45	.20	.05	
GROUP V Air Compressor Operator (two or more compressors); Batch Operator (Asphalt Plant); Motorman; Pavement Breaker Operator (Emsco & similar type); Signalman; Shuttlecar; Small Rubber Tired Tractors; Small Self-propelled Pneumatic Rollers; Towermobile Operator; Welding Machine (2 or more)	5.59	.41	.45	.20	.05	

*AREA 1

POWER EQUIPMENT OPERATORS (Cont'd)	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP TR	OTHERS
GROUP VI A-frame truck & tugger hoist; Concrete Saws (self propelled unit on streets, highways, airports and canals); Engineer, Locomotive; Fork Lift (construction job site); Kelran Loader (and similar); Mayinnia Internal Full Slab Vibrator (on airports, highways, canals and warehouses); Mixermobile Operator; Pipe Bending Machine Operator; Pipe Cleaning Machine; Pipe Wrapping Machine; Road Mixing Machine Operator; Ross Carrier, or similar type, Small Rubber Tired Tractor (with attachments, including backhoe); Small Tractor with Boom; Surface Heater (self-propelled; Loader Operator (over 1 c.y. up to and including 2 c.y. struck MRC); Power Jumbo Operator (setting slip forms, etc. in tunnels); Small Rubber Tired Trenching Machine	5.94	.41	.45	.20	.05	
GROUP VII Bridge Crane; Chip Box Spreader (flaherty type and similar); Concrete Mixer Operator (paving or batch plant); Deck Engineers (Marine); Drilling Machine Operator (well or diamond); Dual Drum Mixers; Elevating Grader Opr.; Fuller Kenyon Pump and similar types; Heavy Duty Rotary Drill Rigs (such as quarry master, joy drills or equal; Hoist Operator - 2 drums; Instrument Man; Mechanical Finisher Operator (Asphalt or concrete); Mine or Shaft Hoist; Pavement Breaker (Pavement Breaker with compressor combination); Pavement Breaker, truck mounted, compressor combination; Refrigeration Plant; Self-Propelled Pipeline, Wrapping machine (Perault, CRC, or similar types); Slusher Operator; Tractor Operator (Sheep's foot and compacting equipment); Trenching Machine; Tractor-Compressor Drill Combination; No- Joint Pipe laying Machine; Pull High-Lift (40 ft. or similar); Roller Operator or self-propelled compactor	6.04	.41	.45	.20	.05	

*AREA 1

POWER EQUIPMENT OPERATORS (Cont'd)	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS H & W	PENSIONS	VACATION	APP. TR	OTHERS
GROUP VII-A Side Boom Operator; Asphalt Plant Engineer; Engineer Crushing Plant; Tractor Operator (bulldozer, scraper or drag-type shovel or boom attachment) (up to and including D-7 or similar)	6.09	.41	.45	.20	.05	
GROUP VIII Do-Mor Loader and Adams Elegrader; Euclid Loader and similar types; Chicago Boom (Including Stiff leg and shear pole); Chief of Party; Combination Slusher and Motor Operaotr; Concrete Batch Plant (Multiple unit); Koehring Skooper (or similar, up to 5c.y. Struck MRC); Loader Operator over 2 c.y. up to and including 5 c.y. Struck MRC; Mucking Machine Operator; Saurman Type Dragline (under 5 c.y. Struck MRC); Self-Propelled Elevating Grade Plane; Soil Stabilizer (P & H or equal); Sub-grader (automatic subgrader - fine - grader); Self-Propelled Boom type lifting device; Mechanical Trench Shield; Rubber Tired Scraper (under 35 c.y. Struck MRC); Tri-Batch Paver; Tunnel (Mole or similar)	6.35	.41	.45	.20	.05	
GROUP VIII-A Heavy duty Repairman or Welder; Tractor Operator Bulldozer, Scraper or Drag type Shovel or Boom Attachment Larger than D-7 or similar	6.40	.41	.45	.20	.05	
GROUP IX Combination Mixer & Compressor (Gunite) Highline Cableway Signalman; Motor Patrol; Tower Crane (Linden type or similar designe and capacity) (in the erection, dismantling & moving of equipment there shall be additional Operator Engineer)	6.45	.41	.45	.20	.05	
GROUP X High Cableway Operator (Signalman required); Lift Slab Machine (Vagborg & similar types); Locomotive (over 100 tons) (single or multiple units); Pre-Stress wire Wrapping Machine; Saurman type dragline (5 c.y. Struck MRC and over						

Decision No. AK-2,013 (3)

*AREA 1

POWER EQUIPMENT OPERATORS (Cont'd)	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP TR	OTHERS
GROUP X (Cont'd) Tractor Tandem Scrapers; DW 10.20 etc. (Tandem Scraper); Universal Equipment Operator (shovel, backhoe, dragline, derrick, derrick barge, clamshell crane, gradall, etc. (up to and including 5 c.y.) Struck MRC; Loader (over 5 c.y. up to and including 12 c.y. Struck MRC)	6.57	.41	.45	.20	.05	
GROUP XI Automatic Concrete Slip Form Paver (Gradesetter, Screedman); Koehring Skooper (or similar) (5 cu. yds. & over Struck MRC); Multiple Propulsion Power Unit Earth Movers (up to and including 75 c.y. Struck MRC); Remote Controlled Cranes and Derricks; Power Equipment with shovel-type controls (over 5 cu. yds. up to and including 7 cu. yds. Struck MRC; Rubber Tired Scraper (35 cu. yds. and over Struck MRC); Self-Propelled Compactor (with multiple propulsion pwoer units); Slip Form Paver (concrete or asphalt) (1 operator and 2 screedman when required); Tandem Tractors; Tower Cranes Mobile	6.90	.41	.45	.20	.05	
GROUP XI-A Multi-purpose Earth Moving Machines; (Two (2) or more scrapers (over 75 c.y. Struck MRC); Power Shovels & Draglines (over 7 c.y. Struck MRC; Loader over 12 c.y. Struck MRC)	7.62	.41	.45	.20	.05	
GROUP XI-B Operator of Helicopter (when used in erection work)	7.96	.41	.45	.20	.05	

Decision No. AK-2,013 (3)

** AREA 2 POWER EQUIPMENT OPERATORS	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP. TR.	OTHERS
GROUP I Chainman; Rodman	5.89	.41	.45	.20	.05	
GROUP II Asphalt Plant Fireman; Brakeman-Locomotive; Elevator Operator; Fireman; Hydraulic Monitor; Material Loader or Conveyor Operator; Partsman - Field; Grade Setter - Repairman Helper - Field	6.09	.41	.45	.20	.05	
GROUP III Air Compressor Operator; Concrete Mixer Operator (skip type); Concrete Pump or Pumpcrete Gun Operator; Engineer, Dinkey Operator; Generator (100 KW or over); Mixer Box Operator (Concrete or Asphalt plant) (continuous mix or similar); Pump Operator; Self-propelled, automatically applied concrete curing machine (on streets, highways, airports and canals); Screedman; Truck Crane Oiler	6.38	.41	.45	.20	.05	
GROUP IV Ballast Jack Tamper; Ballast Regulator; Ballast Tamper-Multiple Purpose; Front End Loader up to and including 1 c.y. Struck MRC; Hoist Operator - 1 Drum; Line Master; Lubrication & Service Engineer (Mobile & Grease Rack); Slip Form Pumps	6.51	.41	.45	.20	.05	
GROUP IV-A Heavy Duty Repairman and Welder Permanent Shop	6.59	.41	.45	.20	.05	
GROUP V Air Compressor Operator (two or more compressors); Batch Operator (Asphalt Plant); Motorman; Pavement Breaker Operator (Emsco & similar type); Signalman; Shuttlecar; Small Rubber Tired Tractors; Small Self-propelled Pneumatic Rollers; Towermobile Operator; Welding Machine (2 or more)	6.59	.41	.45	.20	.05	

Decision No. AK-2,013 (3)

**AREA 2

POWER EQUIPMENT OPERATORS (Cont'd)

	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP. TR.	OTHERS
GROUP VI A-frame truck & tugger hoist; Concrete Saws (self propelled unit on streets, highways, airports and canals); Engineer, Locomotive; Fork Lift (construction job site); Kolman Loader (and similar); Maginnis Internal Full Slab Vibrator (on airports, highways, canals and warehouses); Mixermobile Operator; Pipe Bending Machine Operator; Pipe Cleaning Machine; Pipe Wrapping Machine; Road Mixing Machine Operator; Ross Carrier, or similar type; Small Rubber Tired Tractor (with attachments, including backhoe); Small Tractor with Boom; Surface Heater (self-propelled; Loader Operator (over 1 c.y. up to and including 2 c.y. struck MRC); Power Jumbo Operator (setting slip forms, etc. in tunnels); Small Rubber Tired Trenching Machine	6.94	.41	.45	.20	.05	
GROUP VII Bridge Crane; Chip Box Spreader (flaherty type and similar); Concrete Mixer Operator (paving or batch plant); Deck Engineers (Marine); Drilling Machine Operator (well or diamond); Dual Drum Mixers; Elevating Grader Opr.; Fuller Kenyon Pump and similar types; Heavy Duty Rotary Drill Rigs (such as quarry master, joy drills or equal; Hoist Operator - 2 drums; Instrument Man; Mechanical Finisher Operator (Asphalt or concrete); Mine or Shaft Hoist; Pavement Breaker (Pavement Breaker with compressor combination); Pavement Breaker, truck mounted, compressor combination; Refrigeration Plant; Self-Propelled Pipeline, wrapping machine (Perault, CRC, or similar types); Slusher Operator; Tractor Operator (Sheep's foot and compacting equipment); Trenching Machine; Tractor-Compressor Drill Combination; No- Joint Pipe Laying Machine; Lull High-Lift (40 ft. or similar); Roller Operator or self-propelled compactor	7.04	.41	.45	.20	.05	

Decision No. AK-2,013 (3)

**AREA 2

POWER EQUIPMENT OPERATORS (Cont'd)

	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP TR.	OTHERS
GROUP VII-A Side Boom Operator; Asphalt Plant Engineer; Engineer Crushing Plant; Tractor Operator (bulldozer, scraper or drag-type shovel or boom attachment) (up to and including D-7 or similar)	7.09	.41	.45	.20	.05	
GROUP VIII Do-Mor Loader and Adams Elegrader; Euclid Loader and similar types; Chicago Boom (including Stiff leg and sheer pole); Chief of Party; Combination Slusher and Motor Opereotr; Concrete Batch Plant (Multiple unit); Koehring Skooper (or similar, up to 5c.y. Struck MRC); Loader Operator over 2 c.y. up to and including 5 c.y. Struck MRC; Mucking Machine Operator; Sauerman Type Dragline (under 5 c.y. Struck MRC); Self-Propelled Elevating Grade Plane; Soil Stabilizer (P & H or equal); Sub-grader (automatic subgrader - fine - grader); Self-Propelled Boom type lifting device; Mechanical Trench Shield; Rubber Tired Scraper (under 35 c.y. Struck MRC); Tri-Batch Paver; Tunnel (Mole or similar)	7.35	.41	.45	.20	.05	
GROUP VIII-A Heavy duty Repairman or Welder; Tractor Operator Bulldozer, Scraper or Drag type Shovel or Boom Attachment Larger than D-7 or similar	7.40	.41	.45	.20	.05	
GROUP IX Combination Mixer & Compressor (Gunite); Highline Cableway Signalman; Motor Patrol; Tower Crane (Linden type or similar designs and capacity) (In the erection, dismantling & moving of equipment there shall be additional Operator Engineer)	7.45	.41	.45	.20	.05	
GROUP X High Cableway Operator (Signalman required); Lift Slab Machine (Vagborg & similar types); Locomotive (over 100 tons) (single or multiple units); Pre-Stress wire Wrapping Machine; Sauerman type dragline (5 c.y. Struck MRC and over						

**AREA 2

POWER EQUIPMENT OPERATORS (Cont'd)

	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP. TR.	OTHERS
GROUP X (Cont'd) Tractor Tandem Scrapers; DW 10.20 etc. (Tandem Scraper); Universal Equipment Operator (shovel, backhoe, dragline, derrick, derrick barge, clamshell crane, gradall, etc. (up to and including 5 c.y.) Struck MRC; Loader (over 5 c.y. up to and including 12 c.y. Struck MRC)	7.57	.41	.45	.20	.05	
GROUP XI Automatic Concrete Slip Form Paver (Gradesetter, Screedman); Koehring Skooper (or similar) (5 cu. yds. & over Struck MRC); Multiple Propulsion Power Unit Earth Movers (up to and including 75 c.y. Struck MRC); Remote Controlled Cranes and Derricks; Power Equipment with shovel-type controls (over 5 cu. yds. up to and including 7 cu. yds. Struck MRC; Rubber Tired Scraper (35 cu. yds. and over Struck MRC); Self-Propelled Compactor (with multiple propulsion power units); Slip Form Paver (concrete or asphalt) (1 operator and 2 screedman when required); Tandem Tractors; Tower Cranes Mobile	7.90	.41	.45	.20	.05	
GROUP XI-A Multi-purpose Earth Moving Machines; (Two (2) or more scrapers (over 75 c.y. Struck MRC); Power Shovels & Draglines (over 7 c.y. Struck MRC; Loader over 12 c.y. Struck MRC)	8.62	.41	.45	.20	.05	
GROUP XI-B Operator of Helicopter (when used in erection work)	8.96	.41	.45	.20	.05	

Decision No. AK-2,013 (3)

PILEDRIVING	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP. TR.	OTHERS
GROUP 1						
(a) Assistant to Engineer (Fireman, Oiler, Deckhand)	5.60	.41	.45	.20	.05	
(b) Compressor Operator (Electrically, gas or diesel powered, etc.)	5.83	.41	.45	.20	.05	
(c) Truck Crane Oiler	5.92	.41	.45	.20	.05	
GROUP 2						
(a) Operator of Tugger Hoist (Hoisting materials only)	6.35	.41	.45	.20	.05	
(b) Compressor Operator (2 to 6) (Electrically, gas or diesel powered); Generator op. (electrically, gas or diesel driven, 100 K.W.); Pump op. (2 to 6); Welding machine op. (2 to 6) (Gas or diesel powered)	6.50	.41	.45	.20	.05	
GROUP 3						
"A" Frames; Deck Engineer; Fork Lift Operator; Self propelled Boom Type Lifting Device	6.69	.41	.45	.20	.05	
GROUP 3-A						
Heavy Duty Repairman and/or Welder	6.96	.41	.45	.20	.05	
GROUP 4						
Operating Engineer in lieu of assistant to engineer tending boiler or compressor attached to crane piledriver; Operator of Piledriving rigs, skid or floating & derrick barges; Operator of diesel or gasoline powered Crane Piledriver (w/o boiler) up to & incl. 1 cu. yd. rating; Truck Crane Op. (up to & incl. 25 tons) (hoisting material only) (assistant to engineer required) (not driving piles)	7.33	.41	.45	.20	.05	
GROUP 5						
Operator of diesel or gasoline powered Crane Piledriver (w/o boiler) over 1 cu. yd. rating; Operator of Crane (w/steam, flash boiler, pump or compressor attached); Op. of steam powered crawler or Universal Type Driver (Raymond or similar type); Truck Crane Op. (over 25 tons (Hoisting material or performing piledriving work)	7.43	.41	.45	.20	.05	

Decision No. AK-2,013 (3)

Steel Erection

	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP. TR.	OTHERS
GROUP 1 Assistant to Engineer (Oiler)	5.90	.41	.45	.20	.05	
GROUP 2 Assistant to Engineer (Truck Crane Oiler); Compressor; Generator, gasoline or diesel driven (100 KW)	6.16	.41	.45	.20	.05	
GROUP 3 Compressors, Generators &/or Welding Machines or Combination (2 to 6); Deck Engineer; Instrument Man; Signalman (using mechanical equipment); Fork Lift	6.83	.41	.45	.20	.05	
GROUP 4 Heavy Duty Repairman; Tractor Op.	6.94	.41	.45	.20	.05	
GROUP 4-A Combination Heavy Duty Repairman; Welder	7.13	.41	.45	.20	.05	
GROUP 5 "A" Frame or Boom Truck; Boom Cat; Chicago Boom; Crawler Cranes & Truck Cranes (15 Tons m.r.c. or less) Selfpropelled Boom Type lifting Device; Single Drum Hoist; Tugger Hoist; Chief of Party	7.45	.41	.45	.20	.05	
GROUP 6 Crawler Cranes & Truck Cranes (over 15 tons m.r.c.); Derricks (2 ops. required when swing engine remote from hoist); Highline Cableway (Signalman required); Tower Cranes Mobile; Universal Liebher & Tower Cranes (& similar types) (In the erection, dismantling & moving of equipment, there shall be an additional Operating Engineer); Two or more Drum Hoist	7.73	.41	.45	.20	.05	
GROUP 7 Operator of Helicopter	8.77	.41	.45	.20	.05	

Decision No. AK-2,013 (3)

**AREA 1

TRUCK DRIVERS

	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP. TR	OTHERS
DUMP TRUCKS - Water Level Capacity (bottom end or side) (including Dumpster Trucks, Euclid type trucks, Turnawagons, Turnarockers & Dumpcrete)						
Less than 8 yards	5.30	.30	.20	.30		
8 yards & less than 14 yards	5.45	.30	.20	.30		
14 yards & less than 35 yards	5.60	.30	.20	.30		
35 yards & less than 55 yards	5.80	.30	.20	.30		
55 yards & less than 75 yards	6.00	.30	.20	.30		
75 yards & less than 95 yards	6.20	.30	.20	.30		
95 yards & less than 105 yards	6.40	.30	.20	.30		
Over 105 yards	6.52	.30	.20	.30		
Whenever doubles are used, the drivers will be paid under the appropriate yardage schedule as outlined plus 25¢ per hour.						
When three (3) or more trailers are put into operation, use the appropriate yardage rate as outlined above plus 25¢ per hour for the third (3rd) and each additional trailer which is pulled by one power unit.						
Whenever additional power units are used and operated by one driver, he shall receive an additional 50¢ per hour for operating such equipment.						
FLAT RACK TRUCKS, Bulk Cement Trucks, Transport Trucks, Semi-Trailer (Carrying capacity):						
Pickup	5.125	.30	20	.30		
Less than 10 tons	5.20	.30	.20	.30		
10 tons & less than 15 tons	5.35	.30	.20	.30		
15 tons & less than 20 tons	5.45	.30	.20	.30		
20 tons & over	5.60	.30	.20	.30		
Employees driving any of the above on Flat Rack Trucks with Winch, Hoist Attachments or "A" Frames shall receive $.125 additional per hour when such winch hoist or "A" Frames are in use.						
When drivers load and unload sack cement, explosives and/or railroad ties by hand they shall receive $.15 per hour additional for actual hours worked.						

Decision No. AK-2,013 (3)

**AREA 1

TRUCK DRIVERS - CONT'D

	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS H & W	PENSIONS	VACATION	APP. TR.	OTHERS
TRANSIT MIX TRUCKS:						
4½ yards capacity & less	5.325	.30	.20	.30		
Over 4½ yards capacity to & including 6½ yards	5.425	.30	.20	.30		
Over 6½ yards	5.525	.30	.20	.30		
Concrete pumping trucks	5.525	.30	.20	.30		
WATER, FUEL & OIL TANK TRUCKS:						
0 to 1200 gallons	5.175	.30	.20	.30		
1200 to 2500 gallons	5.30	.30	.20	.30		
2500 to 4000 gallons	5.45	.30	.20	.30		
4000 to 6000 gallons	5.75	.30	.20	.30		
6000 gallons to less than 10,000	6.00	.30	.20	.30		
10,000 gallons to less than 15,000 gallons	6.25	.30	.20	.30		
15,000 gallons to less than 20,000 gallons	6.50	.30	.20	.30		
20,000 gallons to less than 25,000 gallons	6.75	.30	.20	.30		
Over 25,000 gallons	7.00	.30	.20	.30		
Whenever two water tanks are pulled, driver will receive 25¢ per hour in addition to the combined water gallonage rates.						
Oil Spreader Operator (on single man operation where boot man is not required)	6.00	.30	.20	.30		
CONSTRUCTION JOB SERVICEMEN:						
Telescopic Manlift Truck	5.50	.30	.20	.30		
Fork Lift (under 6 tons) & Straddle Truck	5.50	.30	.20	.30		
Truck Driver Helper	5.075	.30	.20	.30		
Chauffeurs	5.075	.30	.20	.30		
Bunker & Truck Loaders	5.20	.30	.20	.30		
Warehousemen (Counter Clerk)	5.25	.30	.20	.30		
Warehousemen	5.125	.30	.20	.30		
Washers, Greasers & Tiremen	5.275	.30	.20	.30		
Gas Station Attendants	5.075	.30	.20	.30		
Fork Lift (Over 6 tons)	5.60	.30	.20	.30		
Material Engineer	5.42	.30	.20	.30		
Teamster Mechanic	6.31	.30	.20	.30		
Teamster Mechanic Helper	6.06	.30	.20	.30		
Teamster Welder	6.31	.30	.20	.30		
Teamster Driving Two Horses	5.075	.30	.20	.30		
Teamster Driving Three or More Horses	5.175	.30	.20	.30		

Decision No. AK-2,013 (3)

**AREA 2

TRUCK DRIVERS	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP TR.	OTHERS
DUMP TRUCKS - Water Level Capacity (bottom end or side) (including Dumpster Trucks, Euclid type trucks, Turnawagons, Turnarockers & Dumpcrete):						
Less than 8 yards	6.30	.30	.20	.30		
8 yards & less than 14 yards	6.45	.30	.20	.30		
14 yards & less than 35 yards	6.60	.30	.20	.30		
35 yards & less than 55 yards	6.80	.30	.20	.30		
55 yards & less than 75 yards	7.00	.30	.20	.30		
75 yards & less than 95 yards	7.20	.30	.20	.30		
95 yards & less than 105 yards	7.40	.30	.20	.30		
Over 105 yards	7.52	.30	.20	.30		
Whenever doubles are used, the drivers will be paid under the appropriate yardage schedule as outlined plus 25¢ per hour.						
When three (3) or more trailers are put into operation, use the appropriate yardage rate as outlined above plus 25¢ per hour for the third (3rd) and each additional trailer which is pulled by one power unit.						
Whenever additional power units are used and operated by one driver, he shall receive an additional 50¢ per hour for operating such equipment.						
FLAT RACK TRUCKS, Bulk Cement Trucks, Transport Trucks, Semi-Trailer (Carrying capacity):						
Pickup	6.125	.30	.20	.30		
Less than 10 tons	6.20	.30	.20	.30		
10 tons & less than 15 tons	6.35	.30	.20	.30		
15 tons & less than 20 tons	6.45	.30	.20	.30		
20 tons & over	6.60	.30	.20	.30		
Employees driving any of the above on Flat Rack Trucks with Winch, Hoist Attachments or "A" Frames shall receive $.125 additional per hour when such winch hoist or "A" Frames are in use.						
When drivers load and unload sack cement, explosives and/or railroad ties by hand they shall receive $.15 per hour additional for actual hours worked.						

Decision No. AK-2,013 (3)

**AREA 2

TRUCK DRIVERS - CONT'D	BASIC HOURLY RATES	FRINGE BENEFITS PAYMENTS				
		H & W	PENSIONS	VACATION	APP. TR.	OTHERS
TRANSIT MIX TRUCKS:						
4½ yards capacity & less	6.325	.30	.20	.30		
Over 4½ yards capacity to & including 6½ yards	6.425	.30	.20	.30		
Over 6½ yards	6.525	.30	.20	.30		
Concrete pumping trucks	6.525	.30	.20	.30		
WATER, FUEL & OIL TANK TRUCKS:						
0 to 1200 gallons	6.175	.30	.20	.30		
1200 to 2500 gallons	6.30	.30	.20	.30		
2500 to 4000 gallons	6.45	.30	.20	.30		
4000 to 6000 gallons	6.75	.30	.20	.30		
6000 gallons to less than 10,000	7.00	.30	.20	.30		
10,000 gallons to less than 15.000 gallons	7.25	.30	.20	.30		
15,000 gallons to less than 20,000 gallons	7.50	.30	.20	.30		
20,000 gallons to less than 25,000 gallons	7.75	.30	.20	.30		
Over 25,000 gallons	8.00	.30	.20	.30		
Whenever two water tanks are pulled, driver will receive 25¢ per hour in addition to the combined water gallonage rates.						
Oil Spreader Operator (on single man operation where boot man is not required)	7.00	.30	.20	.30		
CONSTRUCTION JOB SERVICEMEN:						
Telescopic Manlift Truck	6.50	.30	.20	.30		
Fork Lift (under 6 tons) & Straddle Truck	6.50	.30	.20	.30		
Truck Driver Helper	6.075	.30	.20	.30		
Chauffeurs	6.075	.30	.20	.30		
Bunker & Truck Loaders	6.20	.30	.20	.30		
Warehousemen (Counter Clerk)	6.25	.30	.20	.30		
Warehousemen	6.125	.30	.20	.30		
Washers, Greasers & Tiremen	6.275	.30	.20	.30		
Gas Station Attendants	6.075	.30	.20	.30		
Fork Lift (Over 6 tons)	6.60	.30	.20	.30		
Material Engineer	6.42	.30	.20	.30		
Teamster Mechanic	7.31	.30	.20	.30		
Teamster Mechanic Helper	7.06	.30	.20	.30		
Teamster Welder	7.31	.30	.20	.30		
Teamster Driving Two Horses	6.075	.30	.20	.30		
Teamster Driving Three or More Horses	6.175	.30	.20	.30		

Decision No. AK-2,013 (3)

UTAH
AREA DEFINITIONS
for
Truck Drivers & Operating Engineers

**AREA 2: All areas not included within Area 1 as defined below.

*Area 1: All areas included in the description defined below which is based upon township and range-lines as referenced to the Salt Lake City Base and Meridian:

Commencing at the intersection of the Utah-Nevada border and the Northerly line of Township 36S, thence easterly along the northerly lines of Township 36S to the Northeast corner of Township 36S, Range 17W.

Thence Northerly to the N.W. corner of township 35S, range 16W;
Thence Easterly to the N.E. corner of township 35S, range 16 W;
Thence Northerly to the N.W. corner of township 31S, range 15 W;
Thence easterly to the N.E. corner of township 31S, range 15 W;
Thence Northerly to the N.W. corner of township 26S, range 14 W;
Thence Easterly to the N.E. corner of township 26S, range 14 W;
Thence Northerly to the N.W. corner of township 25S, range 13 W;
Thence Easterly to the N.E. corner of township 25S, range 13 W;
Thence Northerly to the N.W. corner of township 24S, range 12 W;
Thence Easterly to the N.E. corner of township 24 S, range 12 W;
Thence Northerly to the N.W. corner of township 19 S, range 11 W;
Thence Easterly to the N.E. corner of township 19 S, range 11 W;
Thence Northerly to the N.W. corner of township 17 S, range 10 W;
Thence Easterly to the N.E. corner of township 17 S, range 10 W;
Thence Northerly to the N.W. corner of township 16 S, range 9 W;
Thence Easterly to the N.E. corner of township 16 S, range 9 W;
Thence Northerly to the N.W. corner of township 15 S, range 8 W;
Thence Easterly to the N.E. corner of township 15 S, range 8 W;
Thence Northerly to the S.W. corner of township 7 S, range 7 W;
Thence Westerly to the S.W. corner of township 7 S, range 10 W;
Thence Northerly crossing the Salt Lake Base line to the N.W. corner of township 6 N, range 10 W;
Thence Easterly to the N.W. corner of township 6 N, range 8 W;
Thence Northerly to the N.W. corner of township 12 N, range 8 W;
Thence Easterly to the N.E. corner of township 12 N, range 8 W;
Thence Northerly along the Westerly line of range 7 W to the Utah/Idaho border
Thence Easterly along the Utah/Idaho border crossing the Salt Lake Meridian to the Intersection of the Utah/Idaho/Wyoming borders
Thence Southerly along the Utah/Wyoming Border
Thence Easterly along the Utah/Wyoming border to the Easterly line of range 11 E;
Thence Southerly along the East line of range 11 E, crossing the Salt Lake Base line to the N.E. corner of township 4 S, range 11 E;
Thence Easterly to the N.W. corner of township 4 S, range 18 E;
Thence Northerly to the N.W. corner of township 1 S, range 18 E;
Thence Easterly along the Salt Lake Base line to the N.E. corner of township 1 S, range 24 E;
Thence Southerly to the N.E. corner of township 3 S, range 24 E;
Thence Easterly along the Northern line of township 3 S, to the Utah/Colorado border;

UTAH
AREA DEFINITIONS
for
Truck Drivers & Operating Engineers

Thence Southerly along the Utah/Colorado border, to the Southerly line of township 6 S;
Thence Westerly to the N.E. corner of township 7 S, range 23 E;
Thence Southerly to the S.E. corner of township 7 S, range 23 E;
Thence Westerly to the S.W. corner of township 7 S, range 20 E;
Thence Southerly to the S.E. corner of township 8 S, range 19 E;
Thence Westerly to the S.E. corner of township 8 S, range 16 E;
Thence Southerly to the S.E. corner of township 11 S, range 16 E;
Thence Westerly to the S.E. corner of township 11 S, range 14 E;
Thence Southerly to the S.E. corner of township 16 S, range 14 E;
Thence Westerly to the S.E. corner of township 16 S, range 12 E;
Thence Southerly to the S.E. corner of township 20 S, range 12 E;
Thence Westerly to the S.E. corner of township 20 S, range 8 E;
Thence Southerly to the S.E. corner of township 21 S, range 8 E;
Thence Westerly to the S.E. corner of township 21 S, range 6 E;
Thence Southerly to the S.E. corner of township 23 S, range 6 E;
Thence Westerly to the S.E. corner of township 23 S, range 5 E;
Thence Southerly to the N.E. corner of township 27 S, range 5 E;
Thence Easterly to the N.E. corner of township 27 S, range 7 E;
Thence Southerly to the S.E. corner of township 30 S, range 7 E;
Thence Westerly to the S.E. corner of township 30 S, range 4 E;
Thence Southerly to the S.E. corner of township 31 S, range 4 E;
Thence Westerly to the S.W. corner of township 31 S, range 4 E;
Thence Southerly to the S.E. corner of township 35 S, range 3 E;
Thence Westerly to the S.W. corner of township 35 S, range 3 E;
Thence Southerly to the S.E. corner of township 37 S, range 2 E;
Thence Westerly to the S.W. corner of township 37 S, range 2 E;
Thence Southerly to the S.E. corner of township 39 S, range 1 E;
Thence Westerly crossing the Salt Lake Meridian to the S.E. corner of township 39 S, range 2 W;
Thence Southerly to the S.E. corner of township 41 S, range 2 W;
Thence Westerly to the S.E. corner of township 41 S, range 4 W;
Thence Southerly along the Easterly line of range 4 W, to the Utah/Arizona border;
Thence Westerly along the Utah/Arizona border to the S.W. corner of Utah;
Thence Northerly along the Utah/Nevada border to the point of beginning;

* * * * * *

Commencing at the intersection of the Utah/Colorado border and the Southerly line of township 34 S,
Thence Westerly to the S.W. corner of township 34 S, range 21 E;
Thence Northerly to the S.W. corner of township 29 S, range 21 E;
Thence Westerly to the S.W. corner of township 29 S, range 19 E;
Thence Northerly to the N.W. corner of township 23 S, range 19 E;
Thence Easterly to the N.W. corner of township 23 S, range 22 E;
Thence Northerly to the N.W. corner of township 21 S, range 22 E;
Thence Easterly to the N.E. corner of township 21 S, range 24 E;
Thence Southerly to the N.E. corner of township 31 S, range 24 E;
Thence Easterly along the Northerly line of township 31 S, to the Utah/Colorado border;
Thence Southerly along the Utah/Colorado border to the point of beginning.

NOTE: Truck Drivers, only - If any part of portion of any job or project falls within Area 2, then the Area 2 rate of pay will apply for all work done on said job or project. This means, all actual on-site work, such as dams, bridges, roads, etc., including barrow pits which may be located in Area 1.

APPENDIX VI

PROGRAM LISTINGS

SUMMARY

This appendix contains the FORTRAN listing of the computer program developed for simulating the Layout Tunnel and listings of all tunneling subroutines. Definitions of common variables used in these programs are given.

CONTENTS

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CONTENTS (Cont.)

I. COMMON VARIABLE DEFINITIONS

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COMMON /OLDCOM/     PARAMETERS/FLAGS THAT CHANGE WITH TIME

DUMMY(20)       NOT USED AT PRESENT
HEATJ           HEAT ADDED TO TUNNEL FROM WATER JET(OR PROJECTILE)     BTU
IEXCA           STATUS VARIABLE FOR GROUND SUPPORT   1-GROUND SUPPORT FALLEN
                BEHIND EXCAVATOR.0-GROUND SUPPORT NOT BEHIND
IFILD           FLAG INDICATING DISCHARGE AREA IS FILLED
                1-DISCHARGE AREA FILLED.0-DISCHARGE AREA NOT FILLED
JUMIN           STATUS VARIABLE FOR DRILL AND BLAST MOVING OF JUMBO DRILL
                TO FACE   0-MOVING IN PROGRESS. 1-MOVING COMPLETED
JUMOUT          STATUS VARIABLE FOR DRILL AND BLAST MOVING JUMBO DRILL FROM FACE
                0-MOVING IN PROGRESS.1-MOVING COMPLETED
KSTOP(25)       REASON FOR TRAIN/TRUCK I TO HAVE STOPPED
                (SEE APPENDIX IV.DESCRIPTION OF RAIL SYSTEM)
KUNLO           FLAG FOR UNLOADING IN DISCHARGE AREA   1-UNLOADING STOPPED.
                0-UNLOADING CONTINUING
LOADR           STATUS VARIABLE FOR INTEGRATED CONVEYOR LOADER  1-LOADER CAPACITY
                EXCEEDED.0-LOADER CAPACITY NOT EXCEEDED  VARIABLE ALSO USED FOR
                MACHINE LOADERS AND SHOVELS  1-LOADING FINISHED.0-LOADING IN
                PROGRESS
LSTOP           FLAG TO SHUT DOWN OR BRING UP LONG HAUL TRAINS/TRUCKS SYSTEM
                1-SYSTEM SHUT DOWN.0-SYSTEM UP
LVEHCL          STATUS VARIABLE FOR LONG HAUL TRAINS/TRUCKS   0-VEHICLE NOT
                AVAILABLE FOR LOADING.UNEQUAL TO 0- VEHICLE AVAILABLE FOR LOADING
                  EQUIVALENCE (LVEHCL.LTRAIN.LTRUCK)
MACON           STATUS VARIABLE FOR CONVEYOR (LONG HAUL)
                1-MAINTENANCE IN PROGRESS.0- MAINTENANCE COMPLETED
MCAPC           STATUS VARIABLE FOR CONVEYOR(LONG HAUL)  0-CAPACITY OF BELT NOT
                EXCEEDED.1-CAPACITY OF BELT EXCEEDED
MCV             STATUS VARIABLE FOR INTEGRATED CONVEYOR LOADER (OR MACHINE
                LOADERS AND SHOVELS  1-MAINTENANCE IN PROGRESS.0-MAINTENANCE
                COMPLETED
MFLAGC          FLAG TO INDICATE SHORT HAUL MATERIALS HANDLING STOPPED
                0-NOT STOPPED.1 OR GREATER THAN 1-STOPPED
MGS(I)          I=1.5   STATUS VARIABLE FOR GROUND SUPPORT TYPE I
                I=1-NO SUPPORT.I=2-ROCK BOLTS.I=3-SHOTCRETE.I=4-STEEL SETS
                I=5-LAGGING
                0- MAINTENANCE COMPLETED.1-MAINTENANCE IN PROGRESS
MKIN            STATUS VARIABLE FOR MACHINE LOADERS  1-MUCKERS COMPLETED MOVE
                TO FACE .0-MUCKERS MOVE TO FACE IN PROGRESS
MUKOT           STATUS VARIABLE  FOR MACHINE LOADERS  1-MUCKERS COMPLETED
                MOVE FROM FACE.0-MUCKERS MOVE FROM FACE IN PROGRESS
MWJ             STATUS VARIABLE FOR PROJECTILE AND WATER JET  0-OPERATING.
                1 OR GREATER THAN 1 -STOPPED
                EQUIVALENCE(MPI.MWJ)
MWJM            STATUS VARIABLE FOR WATER JET(OR PROJECTILE)0-MAINTENANCE IN
                PROGRESS.1-MAINTENANCE COMPLETED
MWJR            STATUS VARIABLE FOR REPOSITIONING WATER JET(OR PROJECTILE)
                0-REPOSITIONING IN PROGRESS.1-REPOSITIONING COMPLETED
NBARL           STATUS VARIABLE FOR PROJECTILE  0-BARREL REPLACEMENT IN PROGRESS.
                1-BARREL REPLACEMENT COMPLETED
NBYBY           FLAG TO INDICATE FEEDER RUN AWAY TOLERANCE EXCEEDED
                1-TOLERANCE EXCEEDED.0-TOLERANCE NOT EXCEEDED
NCHRG           STATUS VARIABLE FOR DRILL AND BLAST CHARGE SETTING
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               1-CHARGE SETTING COMPLETED.0-CHARGE SETTING IN PROGRESS
NDRILL         STATUS VARIABLE FOR DRILL AND BLAST   0-DRILLING IN PROGRESS.
               1-DRILLING COMPLETED
NDRILB         STATUS VARIABLE FOR DRILL AND BLAST 0-BURN CUT DRILLING IN PROGRESS
               .1-BURN CUT DRILLING COMPLETED
NSPLIC         STATUS VARIABLE FOR CONVEYOR(LONG HAUL)  0-SPLICING BELT COMPLETED
               .UNEQUAL TO 0-SPLICING BELT IN PROGRESS
NSWTCH         STATUS VARIABLE FOR TRAINS/TRUCKS
               0-SWITCH MOVE OR ADD COMPLETED.1-SWITCH BEING ADDED.2-SWITCH
               BEING MOVED
               EQUIVALENCE(NSWTCH.NSWCH)
NTRDA          NUMBER OF TRAINS IN DISCHARGE AREA
NVEHCL         NUMBER OF TRAINS/TRUCKS ACTIVE
                 EQUIVALENCE (NVEHCL.NTRAIN.NTRUCK)
NUMSWT         NUMBER OF SWITCHES IN TRAIN/TRUCK SYSTEM
QL             AVERAGE LOADING VOLUME RATE FOR MACHINE LOADERS AND SHOVELS
               FEET**3/HOUR
QWATR          VOLUME OF WATER ADDED TO TUNNEL FROM WATER JET      FEET**3
SM             FEEDER RUN AWAY TOLERANCE. FT
SWITCH(20)     LOCATION OF SWITCHES   FEET FROM DISCHARGE AREA
TEC(25)        CUMULATIVE COST FOR TRAIN/TRUCK I     $
TOP(25)        CUMULATIVE TIME IN OPERATION FOR TRAIN/TRUCK I   HOURS
TSTAT(25.4)    CURRENT STATUS OF TRAIN/TRUCK I
                 EQUIVALENCE (TSTAT.ITSTAT)
               (SEE APPENDIX IV.DESCRIPTION OF RAIL SYSTEM)
UTIME(25)      TIME REMAINING IN UNLOADING OF TRAIN/TRUCK I. HR
XGS            DISTANCE FROM DISCHARGE AREA TO GROUND SUPPORT POSITION  FEET


COMMON /NEWCOM/     UPDATED VALUES OF THOSE VARIABLES IN /OLDCOM/

EDUMMY(20)          UPDATED VALUES OF DUMMY(20)
EHEATJ         UPDATED VALUE OF HEATJ
LIEXCA         UPDATED VALUE OF IEXCA
LIFILD         UPDATED VALUE OF IFILLD
LJUMIN         UPDATED VALUE OF JUMIN
LJUMOT         UPDATED VALUE OF JUMOUT
LKSTOP(25)     UPDATED VALUE OF KSTOP(25)
LKUNLO         UPDATED VALUE OF KUNLO
LLOADR         UPDATED VALUE OF LOADR
LLSTOP         UPDATED VALUE OF LSTOP
LLVHCL         UPDATED VALUE OF LVEHCL
                 EQUIVALENCE (LLVHCL.LLTRAN.LLTUCK)
LMACON         UPDATED VALUE OF MACON
LMCAPC         UPDATED VALUE OF MCAPC
LMCV           UPDATED VALUE FOR MCV
LMFLAC         UPDATED VALUE OF MFLAGC
LMGS(I)        UPDATED VALUE FOR MGS(I)
LMKIN          UPDATED VALUE OF MKIN
LMUKOT         UPDATED VALUE OF MUKOT
LMWJ           UPDATED VALUE OF MWJ
               EQUIVALENCE(LMPI.LMWJ)
LMWJM          UPDATED VALUE OF MWJM
LMWJR          UPDATED VALUE OF MWJR
LNBARL         UPDATED VALUE OF NBARL
LNBYBY         UPDATED VALUE OF LNBYBY
LNCHRG         UPDATED VALUE OF NCHRG
LNDRIL         UPDATED VALUE OF NDRILL
LNDRLB         UPDATED VALUE OF NDRILB
LNSPLC         UPDATED VALUE OF NSPLIC
LNSWCH         UPDATED VALUE OF NSWCH
LNTRDA         UPDATED VALUE OF NTRDA
                 EQUIVALENCE (LNTRDA.NTDA)
LNVHCL         UPDATED VALUE OF NVEHCL
                 EQUIVALENCE (LNVHCL.LNTRAN.LNTRUK)
LNMSWT         UPDATED VALUE OF NUMSWT
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FQL            UPDATED VALUE OF QL
FQWATR         UPDATED VALUE OF QWATR
FSM            UPDATED VALUE OF SM
FSWTCH(20)     UPDATED VALUE OF SWITCH(20)
FTEC(25)       UPDATED VALUE OF TEC(25)
FTOP(25)       UPDATED VALUE OF TOP(25)
FTSTAT(25,4)   UPDATED VALUE OF TSTAT(25,4)
                 EQUIVALENCE (FTSTAT,LTSTAT)
FUTIME(25)     UPDATED VALUE OF UTIME(25)
FXGS           UPDATED VALUE OF XGS


COMMON /ALL   /     GENERAL DATA

XT             MAXIMUM DISTANCE FROM PORTAL ASSOCIATED WITH THE FOLLOWING SIX
               CONDITIONS   ,FEET
STR            UNCONFINED COMPRESSIVE STRENGTH OF ROCK, 1.E3 LB/IN**2
IA             ROCK ABRASIVE INDEX
RQD            ROCK QUALITY DESIGNATION
CS             IN SITU DENSITY OF ROCKS, LB/FT**3
TAMB           AMBIENT TEMPERATURE, DEGREES FAHRENHEIT
FLOW           WATER INFLOW RATE, GPM
IFLAG          FLAG (NOT USED AT PRESENT)
                 EQUIVALENCE (G(1),XT),(G(8),IFLAG)
AT             CROSS SECTIONAL AREA OF TUNNEL, FT**2
D              DIAMETER OF TUNNEL, FT
DTPRNT         TIME BETWEEN PRINT OUT OF WORKING COMMON   HOURS
DT             TIME INCREMENT, HR
DV             VOLUME OF ROCK BROKEN IN DT, FT**3
DX             ADVANCE OF FACE IN DT, FT
E              ENERGY REQUIRED PER ROCK VOLUMN BROKEN, IN-LB/1.E3 IN**3
ICHNG          FLAG TO INDICATE THAT GEOLOGY HAS CHANGED  0-GEOLOGY NOT CHANGED
               ,1-GEOLOGY CHANGED
XCHNG          HEADING POSITION OF LAST GEOLOGY PARAMETER CHANGE    FT
TCHNG          TIME FROM START OF RUN OF LAST GEOLOGY PARAMETER  CHANGE   HOURS
IMOVE          FLAG TO INDICATE METHOD OF LONG HAUL MATERIALS HANDLING
               1-RAILS,2-TRUCKS,3-BELTS
                 EQUIVALENCE (IMOVE,JMOVE)
JMETH          FLAG TO INDICATE METHOD FOR ROCK FRAGMENTATION
               1-BORING MACHINE,2-BLAST,3-WATER JET,4-PROJECTILE
                 EQUIVALENCE (JMETH,IMETH)
OPPCT          FRACTION OF TOTAL COST FOR OVERHEAD
PR             POWER RATE, $/KW-HR
                 EQUIVALENCE (PR,PC)
REPORT         TIME INTERVALS BETWEEN INTERIM REPORTS(HOURS)
SK             ROCK SWELL FACTOR
T              TIME, HR
TMAX           MAXIMUM TIME FOR CURRENT SIMULATION RUN, HR
TO             INITIAL VALUE OF T    HOURS
TPRINT         PRINT OUTPUT WHEN T=TPRINT, HR
TSHFT          TOTAL SHFT TIME PER DAY     HOURS
X              POSITION OF FACE FROM DISCHARGE AREA,FT
XDISCH         DISTANCE FROM TUNNEL PORTAL TO DISCHARGE AREA   FEET
XMAX           MAXIMUM DISTANCE FOR CURRENT SIMULATION RUN, FT
XO             INITIAL VALUE OF X      FEET


COMMON /BORING/     BORING MACHINE ACTIVITIES

BOMEN(I)       NUMBER OF MEN IN LABOR CATEGORY I (I=1,10) FOR BORING MACHINE
               SYSTEM
BOCST(I)       HOURLY COST OF MAN IN LABOR CATEGORY I FOR BORING MACHINE SYSTEM
CL(3)          LIFE OF CUTTERS   FEET OF CUTTER TRAVEL
CPC            COST PER CUTTER, $
DTA            TIME TO ASSEMBLE BORING MACHINE, HR
DTC            TIME BETWEEN BORING MACHINE MAINTENANCE PERIODS, HR
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DTCD	TIME TO CHANGE BORE DIAMETER, HR
DTD	TIME TO DISASSEMBLE BORING MACHINE, HR
DTM	DURATION OF BORING MACHINE MAINTENANCE, HR
EBOREQ	COST OF BORING MACHINE UNIT/FOOT OF EXCAVATION
ETRANS	COST OF TRANSMISSION LINES/FOOT OF EXCAVATION
KK	NUMBER OF CUTTERS
LNCHNG	NUMBER OF CUTTERS CHANGED
LNCUTR	FLAG FOR CUTTER CHANGE 0-CUTTER CHANGE COMPLETED, I-CUTTERS BEING CHANGED
MASSEM	FLAG TO ASSEMBLE BORING MACHINE
MBM	FLAG FOR BORING MACHINE MAINTENANCE 0-MAINTENANCE COMPLETED,1-MAINTENANCE IN PROGRESS
MBORE	FLAG TO INDICATE STATUS OF BORING MACHINE 0=UP,UNEQUAL 0=DOWN OR IDLE (SEE APPENDIX IV,DESCRIPTION OF CONTROL PROGRAM FOR LAYOUT TUNNEL)
MCD	FLAG FOR CHANGING BORING DIAMETER
MDISAS	FLAG FOR DISASSEMBLY OF BORING MACHINE
NCUT(I)	NUMBER OF THE CUTTER TO BE CHANGED ON THE I TH CHANGE FOR THIS TIME CYCLE I=I,50
PBM	ROTATIONAL HP OF BORING MACHINE, HP
R(100)	RADIAL LOCATIONS OF CUTTERS, IN
RC	CUTTER REPLACEMENT CRITERION, PERCENT WEAR
RPM	ROTATIONAL SPEED OF BORING HEAD, RPM
TR	TIME TO REPLACE ONE CUTTER, HR
WEAR(I)	WEAR OF CUTTER I (I=I,100)
XCPC	CUTTER BEARING COST, PERCENT CUTTER COST

COMMON /BLAST / DRILL AND BLAST ACTIVITIES

ADB	AREA OF BURN CUT RELIEF HOLE, IN**2
ADH	AREA OF DRIFTER HOLE, IN**2
CBIT	DRIFTER BIT COST, $
CBURN	COST OF BURN BIT, $
CCAP	COST OF FIRING CAPS $/CAP
CEX	COST OF EXPLOSIVE $/LB.
CM	MISCELLANEOUS COST $/HOLE
CPL	COST OF PRIMER $/LBS
CSTEEL	COST OF STEEL, $
LBIT	AVERAGE LIFE OF DRILL BIT, FT OF TUNNEL DUG
LBURN	AVERAGE LIFE OF BURN BIT, FT OF TUNNEL DUG
LD	AVERAGE DEPTH OF DRIFTER HOLES, FT
LDB	AVERAGE DEPTH OF BURN CUT HOLES, FT
LSTEEL	AVERAGE LIFE OF STEEL, FT OF TUNNEL DUG
MEN	NUMBER OF MEN OR AUTOMATED UNITS SETTING CHARGE
ND	NUMBER OF DRIFTER DRILLS
NDB	NUMBER OF BURN CUT DRILLS
NH	NUMBER OF DRIFTER HOLES
NHB	NUMBER OF BURN CUT HOLES
PF	POWDER FACTOR, LB/YD**3
POB	POWER OUTPUT OF BURN CUT DRILL, HP
POD	POWER OUTPUT OF DRIFTER DRILL
SF	APPARENT SPECIFIC ENERGY IN-LBS/IN**3
TCHG	TIME TO SET ONE CHARGE, HR
TIN	TIME TO MOVE IN JUMBO AND ALIGN, HR
TOUT	TIME TO MOVE OUT JUMBO, HR
TYPEPF	INDICATES EXPLOSIVE TO BE USED OPTION1-3=AMMONIUM NITRATE OPTION2-0=DYNAMITE
WPL	AMOUNT OF PRIMER PER HOLE, LBS/HOLE

COMMON/NJET/ WATER JET AND PROJECTILE ACTIVITIES

BLT	BARREL OPERATING LIFETIME HOURS
CPBRL	COST PER BARREL FOR PROJECTILE GUN $
CSTPRJ	PROJECTILE COST $/PROJECTILE

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DJMWJM        JOB MATERIAL COST OF MAINTENANCE PERIOD FOR WATER JET
              (OR PROJECTILE)     $/MAINTENANCE PERIOD
DNOZZ         JET NOZZLE DIAMETER       INCHES
DTCJET        TIME BETWEEN MAINTENANCE PERIODS FOR WATER JET(OR PROJECTILE)
              HOURS
DTMJET        LENGTH OF MAINTENANCE PERIOD FOR WATER JET(OR PROJECTILE)
              HOURS
DTRJET        TIME DURATION OF REPOSITIONING OPERATION FOR WATER JET
              (OR PROJECTILE)    HOURS
ENERGJ        JET ENERGY REQUIRED PER VOLUME OF ROCK BROKEN
ETAGN         PROJECTILE GUN EFFICIENCY
ETAJ          EFFICIENCY OF WATER JET DEVICE
ETAIMP        EFFICIENCY OF TRANSMITTING JET ENERGY
ETAIPT        EFFICIENCY OF TRANSMITTING PROJECTILE ENERGY TO ROCK
MODEJ         MODE OF OPERATION   0-CONTINUOUS JET,1-INTERMITTANT JET
NGUNS         NUMBER OF PROJECTILE GUNS
NJETS         NUMBER OF WATER JETS OPERATING
PNOZZ         WATER JET NOZZLE PRESSURE       PSI
PPM           PULSE RATE FOR WATER JET    PULSES/MIN
PRJPM         PROJECTILE GUN FIRING RATE      PROJECTILE/MIN
PULSED        PULSE DURATION FOR WATER JET       SECONDS
TRBRL         TIME TO REPLACE BARREL FOR PROJECTILE GUN   HOURS
VELPRJ        PROJECTILE SPEED      FEET/SEC
VOLPRJ        PROJECTILE VOLUME      INCHES**3
WPRJ          PROJECTILE WEIGHT       LBS.
XRJET         ADVANCE OF TUNNEL BEFORE REPOSITIONING OF WATER JET(OR PROJECTILE)
              IS REQUIRED    FEET


COMMON /WHEELS/   TRAIN/TRUCK AND SHORT HAUL MATERIALS HANDLING ACTIVITIES

AE            PEAK ACCELERATION, EMPTY, MPH/H
AF            PEAK ACCELERATION, FULL,  MPH/H
AMAX          MAXIMUM ACCELERATION, MPH/H
AMAXL         MAXIMUM LOADING AREA, FT
AMINL         MINIMUM LOADING AREA REQUIRED, FT
BSL           DISTANCE BETWEEN SWITCHES, FT
CAPCAP        CAPACITY OF CAR OR TRUCK, YD**3
CP            COST OF FUEL OR POWER TO DRIVE TRAIN/TRUCK  $/HOUR
DE            AVERAGE DECELERATION RATE, EMPTY, MPH/H
DF            AVERAGE DECELERATION RATE, FULL,  MPH/H
DTAS          TIME TO ASSEMBLE CALIFORNIA SWITCH, HR
DTMA          DAYS BETWEEN MAINTENANCE PERIODS, DAYS
DTU           TIME TO UNLOAD ONE TRAIN, HR
FCONED        COST OF CONVEYOR EQUIPMENT/FOOT OF EXCAVATION
FCONSS        COST OF SUPPORTING STRUCTURE FOR CONV-LOAD/FOOT OF EXCAVATION
FL            EFFICIENCY OF LOCOMOTIVE OR POWER TRAIN
FLOCO         COST OF LOCOMOTIVE UNIT          $/HOUR USE
FMUCKC        COST OF MUCK CAR     $/HOUR OF USE
FRMAINT       COST OF MAINTENANCE SHOP FOR RAILS       $/FOOT OF EXCAVATION
FSWITCH       COST OF SWITCH      $/FOOT OF EXCAVATION
FTRACKM       COST OF TRACK MATERIALS     $/FOOT OF EXCAVATION
FUNLOAD       COST OF UNLOADING EQUIPMENT FOR RAILS     $/FOOT OF EXCAVATION
FC            FUEL CONSUMPTION RATE, GAL/HP-HR
FR            ROLLING RESISTANCE FACTOR
FT            TRACTION COEFFICIENT
HPA           PEAK HP AVAILABLE FOR ACCELERATION, HP
HPEA          POWER CONSUMPTION RATE, PEAK ACCEL, EMPTY, HP
HPEV          POWER CONSUMPTION RATE, PEAK VEL, EMPTY, HP
HPFA          POWER CONSUMPTION RATE, PEAK ACCEL, FULL, HP
HPFV          POWER CONSUMPTION RATE, PEAK VEL, FULL, HP
HPV           RATED HP FOR CONTINUOUS OPERATION, HP
IIBORE        FLAG TO INDICATE STATUS OF BORING MACHINE
              EQUIVALENCE(IIBORE,MBORE)
              (SEE APPENDIX IV,DESCRIPTION OF CONTROL PROGRAM FOR LAYOUT TUNNEL)
ISW(25)       INDICATES WHICH SWITCH TRAIN I IS IN
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LOCO	TRAIN OPTION...1=DIESEL, 2=ELECTRIC
LQUE	TRAIN PRIORITY IN LOAD QUEUE
MAXLD	MAXIMUM NUMBER OF TRAINS IN LOADING AREA
MC	NUMBER OF AXLES PER MUCK CAR
ML	NUMBER OF AXLES PER LOCOMOTIVE
MLTYP	INDICATES UNITIZED(2) OR CONTINUOUS(1) CONVEYOR SYSTEM
NCARS	NUMBER OF CARS PER TRAIN
NPOINT	NUMBER OF POINTS IN TCURVX-TCURVY TABLE
NTD	MAXIMUM NUMBER OF TRAINS IN DISCHARGE AREA
NTINIT	INITIAL NUMBER OF TRAINS IN SYSTEM
NTM	MAXIMUM NUMBER OF TRAINS IN MAINTENANCE AREA
NTMAX	MAXIMUM NUMBER OF TRAINS AVAILABLE
XP	DISTANCE CRITERION FOR NTMILP AND NTMLPP
NTMILP	NUMBER OF TRAINS PER MILE FOR X.LE.XP
NTMLPP	NUMBER OF TRAINS PER MILE FOR X.GT.XP
NTRACK	TRACK OPTION...1=SINGLE, 2=DOUBLE
NUMLD	NUMBER OF TRAIN/TRUCK AT FACE
OUC	VOLUME CAPACITY OF TRAIN, FT**3
RAMEN(I)	NUMBER OF MEN IN LABOR CATEGORY I (I=1,10) FOR RAIL SYSTEM
PACST(I)	HOURLY COST OF MAN IN LABOR CATEGORY I FOR RAIL SYSTEM
SL	LENGTH OF CALIFORNIA SWITCH, FT
STATUS(36)	TRAIN STATUS (HOLLERITH)
TCCV	MAINTENANCE PERIOD FOR SHORT HAUL MATERIALS HANDLING HOURS
TMCV	TIME BETWEEN MAINTENANCE PERIODS FOR SHORT HAUL MATERIALS HANDLING HOURS
TMAINT	DURATION OF MAINTENANCE PERIOD FOR TRAINS/TRUCKS HOURS
TCURVX(20)	VELOCITY ENTRY IN VELOCITY-VS-TRACTIVE FORCE TABLE
TCURVY(20)	TRACTIVE FORCE ENTRY IN VELOCITY-VS-TRACTIVE FORCE TABLE
TWE	WEIGHT OF EMPTY TRUCK, TONS
VD	VELOCITY IN DISCHARGE AREA, MPH
VS	VELOCITY IN SWITCH, MPH
VE	PEAK VELOCITY, EMPTY, MPH
VF	PEAK VELOCITY, FULL, MPH
VMAX	MAXIMUM VELOCITY ALLOWED FOR TRAINS, MPH
WC	WEIGHT OF EMPTY MUCK CARS, TONS
WHY(24)	REASON FOR STOPPING (HOLLERITH)
WMR	MAXIMUM MUCKING RATE TONS/HOUR
WUC	WEIGHT CAPACITY OF TRAIN, TONS
WL	WEIGHT OF LOCOMOTIVE, TONS
XDS	SPEED OF MOVING CALIFORNIA SWITCH, FT/HR

COMMON/CONVEY/ CONVEYOR(SHORT AND LONG HAUL) AND MACHINE LOADER ACTIVITIES .

AB	MUCK FLOW CROSS SECTION, FT**2
ACM	MAXIMUM CROSS SECTION OF CONVEYOR STRUCTURE, FT**2
CVMEN(I)	NUMBER OF MEN IN LABOR CATEGORY I (I=1,10) FOR CONVEYOR LOADER
CVCST(I)	HOURLY COST OF MAN IN LABOR CATEGORY I (I=1,10) FOR CONVEYOR LOADER
DMAINT	JOB MATERIAL COST FOR LONG HAUL CONVEYOR MAINTENANCE $/MAINTENANCE PERIOD
DTBS	TIME TO DO A BELT SPLICE(LONG HAUL) HOURS
DTCB	TIME BETWEEN MAINTENANCE PERIODS FOR CONVEYOR(LONG HAUL) HOURS
DTCM	LENGTH OF MAINTENANCE PERIODS FOR CONVEYOR (LONG HAUL) HOURS
DTMI	TIME TO MOVE MUCKERS TO THE FACE (FOR MACHINE LOADERS AND SHOVELS) HOURS
DTMO	TIME TO MOVE MUCKERS AWAY FROM THE FACE(FOR MACHINE LOADERS AND SHOVELS HOURS
DWM	TONNAGE HAULED BEFORE MAINTENENCE SCHEDULED FOR CONVEYOR(LONG HAUL) (ALTERNATIVE TO MAINTENANCE CRITERIA TO DTCB) TONS
EE	MOTOR AND REDUCTION EQUIPMENT EFFICIENCY
FL	LENGTH OF FEEDER FOR CONVEYOR SYSTEM (LONG HAUL) FEET
FLM	MAXIMUM LENGTH OF FEEDER BEFORE BELT SPLICE IS NEEDED(LONG HAUL CONVEYOR) USED IF NGEO(GEOMETRY INDEX) IS 2 FEET
HP	TOTAL HP/LENGTH TO RUN CONVEYOR
LNSURG	FLAG FOR BELT SYSTEM LONG HAUL 1-SURGE BIN CAPACITY EXCEEDED, 0-SURGE BIN CAPACITY NOT EXCEEDED

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NEXON        FLAG FOR BELT/RAIL EXTENSION  1-EXTENSION SHUT DOWN
NGEO         GEOMETRY MODEL INDEX FOR CONVEYOR SYSTEM
             1-CONTINUOUS EXTENSION ASSUMES FEEDER EXTENDS FULL LENGTH OF
             CONVEYOR
             2-CONTINUOUS EXTENSION  ASSUMES FEEDER CONVEYOR EXTENSION IS SMALL(
             (FL=0) AND EMPTIES INTO SHAFT DIRECTLY
             3-CYCLIC EXTENSION USING MINIMUM AND MAXIMUM ALLOWABLE
             DISTANCE FROM FACE FOR BELT
NGEO         GEOMETRY MODEL INDEX FOR TRAIN/TRUCK SYSTEM
             1-CONTINUOUS EXTENSION,2-CYCLIC EXTENSION
NSURGE       STATUS VARIABLE FOR LONG HAUL CONVEYOR SYSTEM
             1-SURGE BIN EXISTS FOR EXCESS  MUCK,0-NO SURGE BIN FOR EXCESS
             MUCK   (LONG HAUL CONVEYOR  )
PC           EQUIVALENCE(PR,PC)     SEE COMMON/ALL/

QUMA         AVERAGE MUCKING RATE CAPABILITY OF MACHINE LOADER   FEET**3/HOUR
QC           SURGE BIN CAPACITY     FEET**3
QE           VOLUME OF MUCK TO BE TAKEN OUT OF OR PUT IN SURGE BIN  FEET**3
QP           PEAK VOLUME RATE OF CONVEYOR, FT**3/HR
SMIN         DISTANCE BETWEEN FACE AND CONVEYOR STRUCTURE, FT
STIME        TIME TO SWITCH UNITS WHEN USING MACHINE LOADERS ANDSHOVELS
             WITH A UNITIZED SYSTEM OF LONG HAUL           HOURS
VBI          BELT SPEED, FT/MIN
WBI          BELT WIDTH, IN
WP           ESTIMATED PEAK TONNAGE RATE, TONS/HR
XE           RAIL/BELT EXTENSION RATE, FT/HR
               EQUIVALENCE (XE,XOE)
XLF          FLIGHT LENGTH, FT

COMMON /GRND  /     GROUND SUPPORT ACTIVITIES

FRBDRI       COST OF ROCK BOLT DRILLS     $/HOUR
FSCPLA       COST OF SHOTCRETE     $/HOUR
GDGW         TIME BETWEEN GROUND SUPPORT MAINTENANCE PERIODS  HOURS
GMEN(I)      NUMBER OF MEN IN LABOR CATEGORY I (I=1,10) FOR GROUND SUPPORT
             SYSTEM
GCST(I)      HOURLY COST OF MAN IN LABOR CATEGORY I FOR GROUND SUPPORT SYSTEM
GSFTDO       LENGTH OF GROUND SUPPORT MAINTENANCE PERIODS   HOURS
GSLDS        GROUND SUPPORT FEET LOST DUE TO ROCK DISINTEGRATION STOPPED
IST          MAJOR GROUND SUPPORT TYPE BEING USED  1-NO SUPPORT,1-ROCK BOLTS,
             3-SHOTCRETE,4-STEEL SETS,5-LAGGING
IAS          ADDITIONAL GROUND SUPPORT TYPE BEING USED  1-NO SUPPORT,
             2-ROCK BOLTS,3-SHOTCRETE,4-STEEL SETS,5-LAGGING
MAXPSS       SUM-I=1,N NO. OF METHODS OF ROCK DISINTEGRATION FOR ROD(I)
             OR =0 IF DEFAULT TABLE IS TO BE USED
PSST(60,9)   PRIMARY GROUND SUPPORT TABLE-SUM-I=1,N NO. METHODS OF ROCK
             FRAGMENTATION FOR EACH ROD        MAXIMUM OF 60
RATERB       RATE OF INSTALLATION OF ROCK BOLTS(ROCKBOLTS/HOURS)
RATESC       RATE OF INSTALLATION OF SHOTCRETE   YARDS**3/HOURS
RATESS       RATE OF INSTALLATION OF STEEL SETS   STEEL SETS/HOURS
UCS          COST OF STEEL   $/LB
UCSC         COST OF SHOTCRETE     $/YARD**3

COMMON /ENVC  /     ENVIRONMENTAL CONTROL ACTIVITIES

AMC(10)      MAXIMUM ALLOWABLE CONCENTRATION OF GAS(N)( PARTS PER 10**6 BY
             VOLUME  DEFAULT=0
CKA          CONDUCTIVITY OF AIR   BTU/HR FT DEGF DEFAULT=.0147
CPA          SPECIFIC HEAT OF AIR    BTU/LB DEG.F
EVENTP       COST OF VENTILATION PLANT   $/FOOT OF EXCAVATION
FKD          FRICTION FACTOR FOR DUCTING      DEFAULT=2.0**-9
FKT          FRICTION FACTOR FOR TUNNEL    DEFAULT=1.5**-8
HEAT         HEAT ADDED TO TUNNEL IN DT FROM MACHINERY BTU
MAXMEN       MAXIMUM NO. OF MEN IN TUNNEL AT ANY TIME     DEFAULT =0
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QD          MINIMUM AIR VOLUME RATE PER DIESEL HORSEPOWER REQ.BY LAW(CFM)
            DEFAULT=106.+.334*TOTHP
QDR         DESIGN REQUIREMENT OF AIR VOLUME RATE (CFM)
QG(10)      VOLUME RATE OF TOXIC GAS(N)  ENTERING TUNNEL (CFM)  DEFAULT=0
QM          MINIMUM AIR VOLUME RATE PER MAN REQUIRED BY LAW (CFM) DEFAULT=200
REFRAT      COST OF MECHANICAL REFRIGERATION PLANT  $/BTU DEFAULT=2.0E-6
TA          AMBIENT TEMPERATURE AT PORTAL  DEG.F   DEFAULT =0
TD          DESIRED AIR TEMPERATURE AT TUNNEL FACE DEG.F  DEFAULT =80.
TOTHP       MAXIMUM TOTAL DIESEL HORSEPOWER IN TUNNEL AT ANYTIME  DEFAULT=0
TROCK       ROCK TEMPERATURE  DEGREES F
VAMAX       MAXIMUM VELOCITY OF AIR AT TUNNEL  FACE(FPM)  DEFAULT=1000
VAMIN       MINIMUM VELOCITY OF AIR AT TUNNEL FACE  (FPM)  DEFAULT=50
VCMEN(I)    NUMBER OF MEN IN LABOR CATEGORY I (I=1,10) FOR VENTILATION AND
            COOLING SYSTEM
VCCST(I)    HOURLY COST OF MAN IN LABOR CATEGORY I FOR VENTILATION AND
            COOLING SYSTEM
WA          DENSITY OF AIR   LBS/FT**3  DEFAULT=.075


COMMON/ PERFRM/   PERFORMANCE OF SYSTEM

DMHTIM      CUMULATIVE DOWN TIME OF MATERIALS HANDLING ACTIVITIES   HOURS
ECDTIM      CUMULATIVE DOWN TIME OF ENVIRONMENTAL CONTROL ACTIVITIES  HOURS
ECUTIM      CUMULATIVE UP TIME OF ENVIRONMENTAL CONTROL ACTIVITIES   HOURS
GADV        AVERAGE ADVANCE DURING MAXIMUM ADVANCE DAY   FEET/OPERATING HOUR
GBEG        POSITION OF FACE FROM PORTAL AT START OF MAX ADVANCE DAY,FT
GDAY        NUMBER OF DAYS SINCE EXCAVATION STARTED AT END OF MAX ADVANCE DAY
GEND        HEADING POSITION (FEET) AT END OF MAXIMUM ADVANCE DAY
GSDTIM      CUMULATIVE DOWN TIME OF GROUND SUPPORT ACTIVITIES   HOURS
GSUTIM      CUMULATIVE UP TIME OF GROUND SUPPORT ACTIVITIES   HOURS
RDDTIM      CUMULATIVE DOWN TIME OF ROCK DISINTEGRATION ACTIVITIES   HOURS
RDUTIM      CUMULATIVE UP TIME OF ROCK DISINTEGRATION ACTIVITIES   HOURS
UMHTIM      CUMULATIVE UP TIME OF MATERIALS HANDLING ACTIVITIES   HOURS


COMMON /MONEY /     COST ITEMS

DJM         JOB MATERIAL COST FOR SETTING CHARGE, $
DJMBM       CUMULATIVE COST FOR MATERIALS HANDLING MAINTENANCE   $
DJMBMM      JOB MATERIAL COST FOR ROCK FRAGMENTATION MAINTENANCE
            $/MAINTENANCE PERIOD
DJMEC       CUMULATIVE COST OF JOB MATERIALS FOR ENVIRONMENTAL CONTROL   $
DJMGS       COST FOR GROUND SUPPORT MAINTENANCE  $/MAINTENANCE PERIOD
DJMMH       JOB MATERIAL COST FOR MATERIALS HANDLING, $ TOTAL
DJMRD       JOB MATERIAL COST FOR ROCK FRAGMENTATION, $ TOTAL
DMAINT      JOB MATERIAL COST FOR BELT MAINTENANCE, $/MAINTENANCE PERIOD
RDTIME      CUMULATED LABOR TIME USED FOR ROCK FRAGMENTATION       HOURS
MTIME(I)    CUMULATIVE LABOR TIME USED FOR MATERIALS HANDLING   HOURS
            I=1-LABOR TIME USED FOR LONG LAUL SYSTEM
            I=2-LABOR TIME USED FOR SHORT HAUL SYSTEM
ECTIME      CUMULATIVE LABOR TIME USED FOR ENVIRONMENTAL CONTROL   HOURS
GSTIME      CUMULATIVE LABOR TIME USED FOR GROUND SUPPORT SYSTEM   HOURS
            ARE INDICES
ECPLAN      TOTAL COST OF PLANT AND EQUIPMENT FOR ENVIRONMENTAL CONTROLS
GSPLANT     TOTAL COST OF PLANT AND EQUIPMENT FOR GROUND SUPPORT        $
MPLANT      TOTAL COST OF PLANT AND EQUIPMENT FOR MATERIALS HANDLING   $
JMCV        COST OF MAINTENANCE FOR INTEGRATED CONVEYOR  $/MAINTENANCE PERIOD
JMMHM       JOB MATERIAL COST FOR TRAIN/TRUCK MAINTENANCE, $/MAINTENANCE PERIOD
PMGS        PERMAMENT MATERIALS COST FOR GROUND SUPPORT $  TOTAL
RDPLAN      TOTAL COST OF PLANT AND EQUIPMENT FOR ROCK DISINTEGRATION  $


COMMON /LABOR/ LABOR COSTS AND MEN

RDMEN(I,J)   I=1,10-LABOR CATEGORIES FOR ROCK FRAGMENTATION
             J=1-NUMBER OF MEN IN LABOR CATEGORY I
```

```
                 J=2-HOURLY COST OF ONE MAN IN LABOR CATEGORY I
                 EQUIVALENCE(ROMEN(I),ROMEN(I,1))
                 EQUIVALENCE(ROCST(I),ROMEN(I,2))
HMEN(I,J,K)      I=1,10-LABOR CATEGORIES FOR MATERIALS HANDLING
                 K=1-LONG HAUL LABOR CATEGORIES
                 J=2-HOURLY COST OF ONE MAN IN LABOR CATEGORY I
                 J=1-NUMBER OF MEN IN LABOR CATEGORY I
                 EQUIVALENCE(RAMEN(I),HMEN(I,1,1))
                 EQUIVALENCE(RACST(I),HMEN(I,2,1))
                 K=2-SHORT HAUL LABOR CATEGORIES
                 J=1-NUMBER OF MEN IN LABOR CATEGORY I
                 J=2-HOURLY COST OF ONE MAN IN LABOR CATEGORY I
                 EQUIVALENCE(CVMEN(I),HMEN(I,1,2))
                 EQUIVALENCE(CVCST(I),HMEN(I,2,2))
GSMEN(I,J)       I=1,10-LABOR CATEGORIES FOR GROUND SUPPORT
                 J=1-NUMBER OF MEN IN LABOR CATEGORY I
                 J=2-HOURLY COST OF ONE MAN IN LABOR CATEGORY I
                 EQUIVALENCE(GMEN(I),GSMEN(I,1))
                 EQUIVALENCE(GCST(I),GSMEN(I,2))
ECMEN(I,J)       I=1,10-LABOR CATEGORIES FOR ENVIRONMENTAL CONTROL
                 J=1-NUMBER OF MEN IN LABOR CATEGORY I
                 J=2-HOURLY COST OF ONE MAN IN LABOR CATEGORY I
                 EQUIVALENCE(VCMEN(I),ECMEN(I,1))
                 EQUIVALENCE(VCCST(I),ECMEN(I,2))
```

II. INPUT FOR LAYOUT TUNNEL

A. CARD IMAGES

```
CARD-IMAGES...

           5    10   15   20   25   30   35   40   45   50   55   60   65   70   75
CARD   ....*....*....*....*....*....*....*....*....*....*....*....*....*....*....*..
   1   BORE        RAILS
   2    $GENERL
   3     D=12.917.DT=.1.T=0..TMAX=25.   .X=12054..XMAX=17092..DTPRNT=1.    .
   4    OPPCT=.1.REPORT=1.    .PR=.02.
   5    XDISCH=12000..
   6    SK=1.7
   7    $END
   8    $BORE
   9    R(1)=2.875.5.75.8.625.11.5.14.375.17.75.20.125.23..25.75.28.5.31.25.
  10    R(12)= 34..36.75.39.5.42.25.45..47.75.50.5.53.25.56..58.75.61.4375.

           5    10   15   20   25   30   35   40   45   50   55   60   65   70   75
CARD   ....*....*....*....*....*....*....*....*....*....*....*....*....*....*....*..
  11    R(23)=63.9375.66.0625.68.1875.70.3125.72.4375.73.6875.74.9375.
  12    PRM=600..RPM=6..DTC=1.4.DTM=6.6.CL=1000000..400000..100000..RC=.90.
  13    KK=29..DTA=176..DTCD=24..TR=.5.FRBORD=34.6.FTRANS=3.4 ,DJMAMM=100..
  14    BOMEN=1.4.1.1                                         .
  15    BOCST=8.46.5.32.8.02.7.11.
  16    CPC=80.XCPC=3.38
  17    $END
  18    $RAILS
  19     NUMLD=3.
  20    NVEHCL=3.NTMAX=4.NTMILP=0.NTMLPP=1.NCARS=10.CARCAP=7..WC=4.05.MC=2.

           5    10   15   20   25   30   35   40   45   50   55   60   65   70   75
CARD   ....*....*....*....*....*....*....*....*....*....*....*....*....*....*....*..
  21    [illegible]
  22    [illegible]
  23    [illegible]
  24    [illegible]
  25    [illegible]
  26    [illegible]
  27    RAMEN=2.2.1.2.1.3.1                                   .
  28    RACST=7.70.7.20.7.70.7.20.8.00.5.32.7.11                          .
  29     FUNLOA=.60.FRMAIN=1.00.CP=.14.JMMHM=50.
  30    $END

           5    10   15   20   25   30   35   40   45   50   55   60   65   70   75
CARD   ....*....*....*....*....*....*....*....*....*....*....*....*....*....*....*..
  31    $LOADER
  32    CVMEN=1.1                    .
  33    CVCST=7.20.7.20                        .
  34    MLTYP=1.WMR=175..TCCV=312..TMCV=8..ECONFQ=4.65.FCONSS =4.00.JMCV=50.
  35    $END
  36    $GROUND
  37     UCS=.13.UCSC=27..RATERH=4..RATFSC=17.5.MAXPSS=0.FRBORT=7.50     .
  38     GMEN=8.2                 .
  39     GCST=7.00.7.20.
  40    FSCPLA=10.00 .DJMGS=50..RATFSS=5.

CARD-IMAGES...

           5    10   15   20   25   30   35   40   45   50   55   60   65   70   75
CARD   ....*....*....*....*....*....*....*....*....*....*....*....*....*....*....*..
  41    $END
  42    $ENVIRC
  43    VCMEN=1.1.2          .
  44    VCCST=8.02.7.11.7.00    .
  45    MAXMEN=40.TOTHP=300..TA=60..EVENTP=1.
  46    $END
```

B. PARAMETER VALUES BEFORE INITIALIZATION BY THE SUBROUTINES

```
$GENERL
D        =  0.12917E+02,
DT       =  0.1E+00,
X        =  0.12054E+05,
XMAX     =  0.17092E+05,
Y        =  0.0,
YMAX     =  0.25E+02,
DTPRNT   =  0.1E+01,
SK       =  0.17E+01,
PR       =  0.2E-01,
OPPCT    =  0.1E+00,
REPORT   =  0.1E+01,
XMESCH   =  0.12E+05,
Z        =  0.0,
$END
```

```
$BORE
CL      =  0.1E+07,  0.4E+06,  0.1E+06,
CPC     =  0.8E+02,
DTA     =  0.176E+03,
DTC     =  0.14E+01,
DTCO    =  0.24E+02,
DTD     =  0.0,
DTM     =  0.66E+01,
KK      =  29,
PRM     =  0.6E+03,
R       =  0.2875E+01,  0.575E+01,  0.8625E+01,  0.115E+02,  0.14375E+02,  0.1775E+02,  0.20125E
           0.2575E+02,  0.295E+02,  0.3125E+02,  0.34E+02,  0.3675E+02,  0.395E+02,  0.4225E+02,
           0.4775E+02,  0.505E+02,  0.5325E+02,  0.56E+02,  0.5875E+02,  0.614375E+02,  0.639375
           0.681875E+02,  0.703125E+02,  0.724375E+02,  0.736875E+02,  0.749375E+02,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
RC      =  0.9E+00,
RPM     =  0.6E+01,
TR      =  0.5E+00,
XCPC    =  0.338E+01,
EBOREQ  =  0.346E+02,
FTRANS  =  0.34E+01,
DJMBMM  =  0.1E+03,
BOMEN   =  0.1E+01,  0.4E+01,  0.1E+01,  0.1E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
BOCST   =  0.846E+01,  0.532E+01,  0.802E+01,  0.711E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
$END
```

```
$RAILS
AF       =  0.0,
AF       =  0.0,
AMAX     =  0.72E+03,
AMAXL    =  0.276E+03,
AMINL    =  0.276E+03,
BSL      =  0.865E+04,
CARCAP   =  0.7E+01,
CP       =  0.14E+00,
DF       =  0.72E+03,
DF       =  0.72E+03,
DYAS     =  0.11E+02,
DYMA     =  0.916E+00,
DTU      =  0.17E+00,
NSWCH    =  0,
NGEO     =  1,
NEXON    =  0,
XDF      =  0.12E+02,
AB       =  0.0,
VB1      =  0.0,
SN       =  0.75E+02,
FL       =  0.0,
FC       =  0.0,
FR       =  0.0,
FT       =  0.0,
HPA      =  0.14E+03,
HPFV     =  0.0,
HPEA     =  0.0,
HPFV     =  0.0,
HPFA     =  0.0,
HPFV     =  0.0,
```

```
HPV     =  0.1E+03.
LOCO    =  1.
MC      =  2.
ML      =  2.
NCARS   =  10.
NPOINT  =  0.
NTD     =  1.
NTM     =  2.
NTMAX   =  4.
XP      =  0.1E+02.
NTMILP  =  0.
NTMLPP  =  1.
NTRACK  =  1.
SL      =  0.3ME+03.
TCURVX  =  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0
           0.0.  0.0.
TCURVY  =  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0
           0.0.  0.0.
TMAINT  =  0.2E+01.
TWE     =  0.0.
VD      =  0.1E-01.
VS      =  0.2E+01.
VF      =  0.0.
VF      =  0.0.
VMAX    =  0.12E+02.
WC      =  0.405E+01.
WL      =  0.1E+02.
XDS     =  0.2E+04.
MAXLD   =  1.
NVEHCL  =  1.
NUMSWT  =  1.
SWITCH  =  0.11469E+05.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.  0.0.
           0.0.  0.0.  0.0.
```

```
ISTA    = 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
TPOS    = 0.11469E+05, 0.11469E+05, 0.11469E+05, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0
          0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.1,
TSPD    = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0
          0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
TMAIN   = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0
          0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
KSTOP   = 1, 101, 102, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
MLTYP   = 0,
WMR     = 0.0,
FLOCO   = 0.15E+01,
FMUCKC  = 0.17E+00,
FTRACK  = 0.75E+01,
FSWITC  = 0.0,
FUNLOA  = 0.6E+00,
FRMAIN  = 0.1E+01,
JMMMM   = 0.6E+02,
NUMLD   = 3,
ISW     = 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
RAMEN   = 0.2E+01, 0.2E+01, 0.1E+01, 0.2E+01, 0.1E+01, 0.3E+01, 0.1E+01, 0.0, 0.0, 0.0
RACST   = 0.77E+01, 0.72E+01, 0.77E+01, 0.72E+01, 0.8E+01, 0.532E+01, 0.711E+01, 0.0, 0
$END
```

```
$LOADER
AR      =  0.0,
VRI     =  0.0,
SM      =  0.75E+02,
TCCV    =  0.312E+03,
TMCV    =  0.8E+01,
WMR     =  0.175E+03,
MLTYP   =  1,
ECONFO  =  0.465E+01,
FCONSS  =  0.4E+01,
JMCV    =  0.5E+02,
CVMFN   =  0.1E+01,  0.1E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
CVCST   =  0.72E+01,  0.72E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
$END
```

```
$GROUND
UCS      =  0.13E+00,
UCSC     =  0.27E+02,
RATERR   =  0.4E+01,
RATESC   =  0.175E+02,
RATESS   =  0.5E+01,
MAXPSS   =  0,
ERRORT   =  0.75E+01,
ESCPLA   =  0.1E+02,
DJMGS    =  0.5E+02,
GDOW     =  0.0,
GSETDO   =  0.0,
GMEN     =  0.8E+01,  0.2E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
GCST     =  0.7E+01,  0.72E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
$END
```

```
$ENVIRC
EVENTP  = 0.1E+01,
MAXMFN  = 40.,
TOTHP   = 0.3E+03,
TA      = 0.6E+02,
DH      = 0.0,
DD      = 0.0,
VAMIN   = 0.0,
VAMAX   = 0.0,
TD      = 0.0,
WA      = 0.0,
CPA     = 0.0,
CWA     = 0.0,
REFRAT  = 0.0,
AMC     = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
VCMFN   = 0.1E+01, 0.1E+01, 0.2E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
VCCST   = 0.802E+01, 0.711E+01, 0.7E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
CPUMP   = 0.0,
FKT     = 0.0,
$END
```

TUNNEL CROSS SECTION = 131.0428 SQ FT

RAIL PARAMETERS = VF 12.000 VF 12.000 RF 742.170 RF 916.050 GE 50.500 GF 145.000 HPFV 29.687 HPFV 36.642

TRAIN CAPACITY = 1890.0000 CUBIC FEET AND 94.5000 TONS

RAIL EXTENSION - EXT. RATE = 12.00 SWITCH MOVE RATE = 2000.00 DISTANCE BETWEEN SWITCHES = 8

RAIL MAINT. PARAMETERS - TIME TO REPAIR = 2.00 COST OF MATERIALS = 50.00 DAYS BETWEEN MAI

	PRIMARY GROUND SUPPORT							
ROD	EXCAVATION PROCESS	UNSUPPORTED LENGTH-MAX FT	INTERFERENCE LENGTH FT	SUPPORT TYPE	SPACING FT	THICKNESS IN	[illegible]	AR
95.00	5.00	999999.00	0.00	1.00	0.00	0.00	0.00	
90.00	5.00	999999.00	0.00	1.00	0.00	0.00	0.00	
90.00	2.00	10.00	0.00	3.00	0.00	5.00	0.00	
75.00	5.00	8.00	0.00	3.00	0.00	1.00	0.00	
75.00	1.00	8.00	4.00	3.00	0.00	1.00	0.00	
75.00	2.00	5.00	[illegible]	2.00	5.00	[illegible]	[illegible]	
50.00	5.00	6.00	0.00	3.00	0.00	3.00	0.00	
50.00	1.00	6.00	0.00	3.00	0.00	3.00	0.00	
50.00	2.00	4.00	0.00	4.00	4.00	0.00	0.00	
25.00	5.00	5.00	0.00	3.00	0.00	5.00	1.00	
25.00	1.00	5.00	4.00	4.00	3.00	0.00	0.00	
25.00	2.00	3.00	[illegible]	4.00	3.00	[illegible]	[illegible]	
0.00	5.00	2.00	0.00	4.00	2.00	6.00	0.00	
0.00	1.00	2.00	4.00	4.00	2.00	8.00	0.00	
0.00	2.00	2.00	0.00	4.00	2.00	0.00	0.00	

NOTE. EXCAVATION PROCESS =5 INDICATES ANY PROCESS OTHER THAN THOSE IN TABLE

C. PARAMETER VALUES AFTER INITIALIZATION BY THE SUBROUTINES

```
$GENERL
D        =  0.12917E+02,
DT       =  0.1E+00,
X        =  0.12054E+05,
XMAX     =  0.17092E+05,
T        =  0.0,
TMAX     =  0.25E+02,
DTPRNT   =  0.1E+01,
SK       =  0.17E+01,
PR       =  0.2E-01,
OPPCT    =  0.1E+00,
REPORT   =  0.1E+01,
XDISCH   =  0.12E+05,
E        =  0.0,
$END
```

```
$BORE

CL       =  0.1E+07,  0.4E+06,  0.1E+06,

CPC      =  0.8E+02,

DTA      =  0.176E+03,

DTC      =  0.14E+01,

DTCD     =  0.24E+02,

DTD      =  0.0,

DTM      =  0.66E+01,

KK       =  29,

PRM      =  0.6E+03,

R        =  0.2875E+01,  0.575E+01,  0.8625E+01,  0.115E+02,  0.14375E+02,  0.1775E+02,  0.20125E
            0.2575E+02,  0.295E+02,  0.3125E+02,  0.34E+02,  0.3675E+02,  0.395E+02,  0.4225E+02,
            0.4775E+02,  0.505E+02,  0.5325E+02,  0.56E+02,  0.5875E+02,  0.614375E+02,  0.639375
            0.681875E+02,  0.703125E+02,  0.724375E+02,  0.736875E+02,  0.749375E+02,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

RC       =  0.9E+00,

RPM      =  0.6E+01,

TR       =  0.5E+00,

XCPC     =  0.338E+01,

FBORED   =  0.346E+02,

FTRANS   =  0.34E+01,

DUMMY    =  0.1E+03,

BOMEN    =  0.1E+01,  0.4E+01,  0.1E+01,  0.1E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

BOCST    =  0.846E+01,  0.532E+01,  0.802E+01,  0.711E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

$END
```

```
$RAILS
AF       =  0.0.
AF       =  0.0.
AMAX     =  0.72E+03.
AMAXL    =  0.276E+03.
AMINL    =  0.276E+03.
BSL      =  0.865E+04.
CARCAP   =  0.7E+01.
CP       =  0.14E+00.
DF       =  0.72E+03.
DF       =  0.72E+03.
DTAS     =  0.11E+02.
DTMA     =  0.916E+00.
DTU      =  0.17E+00.
NSWCH    =  0.
NGEO     =  1.
NEXON    =  0.
XDE      =  0.12E+02.
AB       =  0.0.
VBI      =  0.0.
SM       =  0.75E+02.
EL       =  0.8E+00.
FC       =  0.455E-01.
FR       =  0.0.
FY       =  0.25E+00.
HPA      =  0.14E+03.
HPEV     =  0.29686781909005E+02.
HPEA     =  0.0.
HPEV     =  0.29686781909005E+02.
HPEA     =  0.0.
HPEV     =  0.36641991909005E+02.
```

```
HPV     =  0.1E+03,
LOCO    =  1,
MC      =  2,
ML      =  2,
NCARS   =  10,
NPOINT  =  0,
NTO     =  1,
NTM     =  2,
NTMAX   =  4,
XP      =  0.1E+02,
NTMILP  =  0,
NTMLPP  =  1,
NTRACK  =  1,
SL      =  0.36E+03,
TCURVX  =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0
           0.0,  0.0,
TCURVY  =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0
           0.0,  0.0,
TMAINT  =  0.2E+01,
TWF     =  0.0,
VD      =  0.1E-01,
VS      =  0.2E+01,
VF      =  0.12E+02,
VF      =  0.12E+02,
VMAX    =  0.12E+02,
WC      =  0.405E+01,
WL      =  0.1E+02,
XDS     =  0.2E+04,
MAXLD   =  3,
NVEHCL  =  3,
NUMSWT  =  1,
SWITCH  =  0.11469E+05,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,
```

```
ISTA    =  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0

IPOS    =  0.11469E+05,  0.11469E+05,  0.11469E+05,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

ISPD    =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

IMAIN   =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

KSTOP   =  1.  101.  102.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0

MLTYP   =  1.

WMR     =  0.175E+03.

FLOCO   =  0.15E+01.

FMUCKC  =  0.17E+00.

FTRACK  =  0.75E+01.

FSWITC  =  0.0.

FUNLOA  =  0.6E+00.

FRMAIN  =  0.1E+01.

JMMHM   =  0.5E+02.

NUMLO   =  2.

ISW     =  1.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0

RAMEN   =  0.2E+01.  0.2E+01.  0.1E+01.  0.2E+01.  0.1E+01.  0.3E+01.  0.1E+01.  0.0.  0.0.  0.0

RACST   =  0.77E+01.  0.72E+01.  0.77E+01.  0.72E+01.  0.8E+01.  0.532E+01.  0.711E+01.  0.0.  0

$END
```

```
$GROUND
UCS      =  0.13E+00,
UCSC     =  0.27E+02,
RATERB   =  0.4E+01,
RATESC   =  0.175E+02,
RATESS   =  0.5E+01,
MAXPSS   =  0,
ERRORI   =  0.75E+01,
ESCPLA   =  0.1E+02,
OJMGS    =  0.5E+02,
GOOW     =  0.0,
GSETOO   =  0.0,
GMEN     =  0.8E+01, 0.2E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
GCST     =  0.7E+01, 0.72E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
$END
```

```
$LOADER
AB       =  0.0,
VRT      =  0.0,
SM       =  0.75E+02,
TCCV     =  0.312E+03,
TMCV     =  0.8E+01,
NMR      =  0.175E+03,
MLTYP    =  1,
ECONEQ   =  0.465E+01,
ECONSS   =  0.4E+01,
JMCV     =  0.5E+02,
CVMEN    =  0.1E+01,  0.1E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
CVCST    =  0.72E+01,  0.72E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
$END
```

```
$ENVIRC
EVENTP  =  0.1E+01,
MAXMEN  =  40,
TOTHP   =  0.3E+03,
TA      =  0.6E+02,
QM      =  0.2E+03,
QD      =  0.2062E+03,
VAMIN   =  0.5E+02,
VAMAX   =  0.1E+04,
TD      =  0.8E+02,
WA      =  0.75E-01,
CPA     =  0.24E+00,
CKA     =  0.147E-01,
REFRAT  =  0.2E-05,
AMC     =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
VCMEN   =  0.1E+01,  0.1E+01,  0.2E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
VCCST   =  0.802E+01,  0.711E+01,  0.7E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
CPUMP   =  0.0,
FKT     =  0.15E-07,
$END
```

III. PROGRAMS AND SUBROUTINES

A. PROGRAM GEOMOD

```
      PROGRAM GEOMOO
C                         GENERATES GEOLOGY FILE
C
      COMMON /IOCOM/ NLINE,NPAGE
C
      DIMENSION SURF(30,30,7),PROP(6,25),SPEC(7),INDEX(25),BUFF(27)
C
   10 FORMAT (1H1,///////////////,25X,86HEEEEEEE  X    X   CCCCCC    AAAA
     A V       V    AAAA     TTTTTTT  I     000000    NN    N,/,25X,86HE
     B      X X   C          A    A     V     V    A    A       T     I    O
     C      O   N N   N,/,25X,86HEEEE        X     C          AAAAAAAA     V
     D V    AAAAAAAA      T      I    O        O   N   N  N,/25X,86HE           X
     E X   C          A      A     V V      A       A      T      I    O       O
     F   N   N N,/,25X,86HEEEEEEE  X     X    CCCCCC  A      A       V        A
     G      A      T      I     000000    N     NN,////,
     H                                                45X,40HM      M    000000
     I DDDDD    EEEEEE   L,/,45X,40HMMM   MM   O       O   D    O   E
     J   L,/,45X,40HM M M M    O        O    D    O   EEEE     L,/,45X,40HM
     K M  M   O        O   D    O   E             L,/,45X, 46HM       M    000000
     L    DDDDD    EEEEEE   LLLLLLL,//////////,27X,14HPREPARED FOR  ,59X
     M,4HBY  ,//,14X,40HUNITED STATES DEPARTMENT OF THE INTERIOR,34X,28H
     NGENERAL RESEARCH CORPORATION,//,26X,15HBUREAU OF MINES,50X,21HWASH
     OINGTON OPERATIONS,//,17X,34HBUILDING 20, DENVER FEDERAL CENTER,35X
     P,32H1501 WILSON BOULEVARD, SUITE 700,//22X,24HDENVER, COLORADO   8
     Q0225,43X,26HARLINGTON, VIRGINIA  22209,///,53X,30HUNDER CONTRACT N
     RUMBER H0110233)
C
      NLINE=999
      NPAGE=0
C     *****B5500
C     READ (30,20,END=30) TAG1,TAG2, (SPEC(I),I=1,7)
C     GO TO 50
C     *****
C     *****CDC6400
      READ 20, TAG1,TAG2,(SPEC(I),I=1,7)
      IF (EOF,49) 30,50
C     *****
   20 FORMAT (2A5,7F10.0)
   30 PRINT 40
   40 FORMAT (1H1,31(1H*),68H ABNORMAL ENDING - END OF INPUT FILE REACHE
     -D - EXECUTION TERMINATED ,32(1H*))
   45 PRINT 10
      PRINT 10
      CALL EXIT
   50 PRINT 10
      PRINT 10
   60 IF (TAG1.EQ.5HGEOLO) GO TO 80
      PRINT 70
   70 FORMAT (1H1,13(1H*),104H THE FIRST CARD HAS TO BE A GEOLOGY CARD -
     - PLEASE REFER TO PROGRAM DOCUMENTATION - EXECUTION TERMINATED ,
     - 13(1H*))
      STOP
   80 NX=SPEC(1)
      SCALEX=SPEC(2)
      NY=SPEC(3)
      SCALEY=SPEC(4)
      CALL PAGER(2)
      PRINT 90, TAG1,TAG2,(SPEC(I),I=1,7)
      NLINE=NLINE+2
   90 FORMAT (//,26X,2A5,7F10.4)
C
C     *****B5500
C 100 READ (30,20,END=30) TAG1,TAG2, (SPEC(I),I=1,7)
```

```
C     *****
C     *****CDC6400
  100 READ 20, TAG1,TAG2,(SPEC(I),I=1,7)
      IF (EOF,49) 30,110
C     *****
  110 CALL PAGER(2)
      PRINT 90, TAG1,TAG2,(SPEC(I),I=1,7)
      NLINE=NLINE+2
C
      IF (TAG1.NE.5HGEOLO) GO TO 130
      PRINT 120
  120 FORMAT (1H0,38(1H*),58H ERROR - TWO GEOLOGY CARDS PRESENT - EXECUT
     -ION TERMINATED ,37(1H*))
      GO TO 45
C
  130 IF (TAG1.NE.5HSURFA) GO TO 160
      K=SPEC(1)
C     *****B5500
C 140 READ (30,20,END=30) TAG1,TAG2, (SPEC(I),I=1,7)
C     *****
C     *****CDC6400
  140 READ 20, TAG1,TAG2,(SPEC(I),I=1,7)
      IF(EOF,49) 30,145
C     *****B5500
  145 IF(TAG1 .NE. 5H     ) GO TO 110
      CALL PAGER(2)
      PRINT 90, TAG1,TAG2,(SPEC(I),I=1,7)
      NLINE=NLINE+2
      I=SPEC(1)
      J=SPEC(2)
      IF (I*J.LE.0) GO TO 150
      SURF(I,J,K)=SPEC(3)
  150 I=SPEC(4)
      J=SPEC(5)
      IF (I*J.LE.0) GO TO 140
      SURF(I,J,K)=SPEC(6)
      GO TO 140
C
  160 IF (TAG1.NE.5HPLANE) GO TO 190
      K=SPEC(1)
      DEPTH=SPEC(2)
      DO 180 I=1,NX
      DO 170 J=1,NY
      SURF(I,J,K)=DEPTH
  170 CONTINUE
  180 CONTINUE
      GO TO 100
C
  190 IF (TAG1.NE.5HRAISE) GO TO 230
  200 K=SPEC(1)
      DIST=SPEC(2)
      DO 220 I=1,NX
      DO 210 J=1,NY
      SURF(I,J,K)=SURF(I,J,K)+DIST
  210 CONTINUE
  220 CONTINUE
      GO TO 100
C
  230 IF (TAG1.NE.5HLOWER) GO TO 240
      SPEC(2)= -SPEC(2)
      GO TO 200
C
  240 IF (TAG1.NE.5HTILT ) GO TO 250
      IA=SPEC(1)
      IB=SPEC(2)
      DEG=SPEC(3)
```

```
      AXIS=SPEC(4)
      PTX=SPEC(5)
      PTY=SPEC(6)
      PTZ=SPEC(7)
      CALL TILT(NX,NY,SCALEX,SCALEY,SURF(1,1,IA),
     1             DEG,AXIS,SURF(1,1,IB),PTX,PTY,PTZ)
      GO TO 100
C
  250 IF (TAG1.NE.5HBEND ) GO TO 260
      IA=SPEC(1)
      ID=SPEC(2)
      IC=SPEC(3)
      IB=SPEC(4)
      SCOPE=SPEC(5)
      IF (SCOPE.EQ.0.0)  SCOPE=AMINO(NX,NY,3)
      CALL BENDER (NX,NY,SCALEX,SCALEY,SURF(1,1,IA),SURF(1,1,IB),
     1                SURF(I,1,IC),SURF(1,I,ID),SCOPE,DUMMY,DUMMY)
      GO TO 100
C
  260 IF (TAG1.NE.5HPROPE) GO TO 280
      J=SPEC(I)
      DO 270 I=1,6
      PROP(I,J)=SPEC(I+1)
  270 CONTINUE
      GO TO 100
C
  280 IF (TAG1.NE.5HGRAPH) GO TO 290
      CALL EPAGE
      N=1
  283 K=SPEC(N)
      IF (SPEC(N).LE.0.0) GO TO 266
      CALL GRAPH (SURF(I,I,K),NX,NY,K)
      N=N+I
      IF (N.LT.8) GO TO 283
  266 CALL PAGER(999)
      GO TO 100
C
  290 IF (TAG1.NE.5HLAYER) GO TO 310
      ISURF=SPEC(1)
      IROCK=SPEC(2)
      ILAYR=SPEC(3)
      INDEX(ILAYR)=IROCK
      WRITE(ILAYR,300) ((SURF(1,J,ISURF),1=1,NX),J=1,NY)
  300 FORMAT ((1PE18.10))
      GO TO 100
  310 IF (TAG1.NE.5HRELAX) GO TO 320
      K=SPEC(1)
      TOLER=SPEC(2)
      IF (TOLER.EQ.0.0) TOLER=0.005*(SCALEX*SCALEY)
      CALL RELAX(SURF(1,1,K),NX,NY,TOLER)
      GO TO 100
  320 IF (TAG1.NE.5HMAKEF) GO TO 460
      IMAXR=SPEC(1)
      IMAXL=SPEC(2)
      REWIND 50
      WRITE (50,330) NX,NY,SCALEX,SCALEY,(INDEX(ILAYR),ILAYR=1,25),
     1                ((PROP(I,IROCK),1=I,6),IROCK=1,25)
  330 FORMAT (2I5,2(1PE18.10),25I2,(1PE18.10))
      DO 340 I=I,IMAXL
      REWIND 1
  340 CONTINUE
      DO 380 J=1,NY
      DO 370 I=1,NX
      BUFF(I)=I
      BUFF(2)=J
      DO 350 K=3,27
```

```
      BUFF(K)= -10.0 E+50
  350 CONTINUE
      DO 360 K=1,IMAXL
C     *****B5500
C     READ (K,300,END=420) BUFF (K+2)
C     *****
C     *****CDC6400
      READ (K,300) BUFF(K+2)
      IF (EOF,K) 420,360
C     *****
  360 CONTINUE
      WRITE (50,300) (BUFF(K),K=1,27)
  370 CONTINUE
  380 CONTINUE
      CALL EPAGE
      PRINT 390
  390 FORMAT (27H1GEOMOD TERMINATED NORMALLY)
      GO TO 45
  400 PRINT 410
  410 FORMAT (1H*,24H***** UNRECOGNIZED *****,
     1        82X,24H***** UNRECOGNIZED *****)
      GO TO 100
  420 CALL EPAGE
  430 PRINT 440,K
  440 FORMAT (44H0LOGICAL ERROR - YOU ATTEMPTED TO USE LAYER ,I1,
     1        52H, BUT DID NOT SPECIFY IT BY MEANS OF A LAYER CARD - ,
     2        30HGEOLOGY FILE BUILDING DELETED.)
  450 IF (K.GE.IMAXL) GO TO 45
      K=K+1
C     *****B5500
C     READ (K,300,END=430) BUFF (K+2)
C     GO TO 450
C     *****
C     *****CDC6400
      READ(K,300) BUFF(K+2)
      IF (EOF,K) 430,450
C     *****
  460 IF (TAG1.NE.5HSCALE) GO TO 490
      ISURFA=SPEC(1)
      ISURFB=SPEC(2)
      SCALE=SPEC(3)
      DO 480 J=1,NY
      DO 470 I=1,NX
      SURF(I,J,ISURFB)=SCALE*SURF(I,J,ISURFA)
  470 CONTINUE
  480 CONTINUE
      GO TO 100
  490 IF (TAG1.NE.5HSUM  ) GO TO 520
      ISURFA=SPEC(1)
      ISURFB=SPEC(2)
      ISURFC=SPEC(3)
      DO 510 J=1,NY
      DO 500 I=1,NX
      SURF(I,J,ISURFC)=SURF(I,J,ISURFA)+SURF(I,J,ISURFB)
  500 CONTINUE
  510 CONTINUE
      GO TO 100
  520 IF (TAG1.NE.5HDIFFE) GO TO 400
      ISURFA=SPEC(1)
      ISURFB=SPEC(2)
      ISURFC=SPEC(3)
      DO 540 J=1,NY
      DO 530 I=1,NX
      SURF(I,J,ISURFC)=SURF(I,J,ISURFA)-SURF(I,J,ISURFB)
  530 CONTINUE
  540 CONTINUE
```

```
      GO TO 100
      END
      SUBROUTINE BENDER(NX,NY,SCALEX,SCALEY,A,B,C,D,E,F,G)
C
      DIMENSION A(30,30),B(30,30),C(30,30),D(30,30),BX(30,30),
     1          BY(30,30),CLOSE(50,4),POINT(3,900),Q(6)
C
C     COMPUTE THE PARTIAL DERIVATIVES FOR SURFACE B, THE NEW MEDIAN.
C
      DX=0.5/SCALEX
      DY=0.5/SCALEY
      INFLUN=E
      LIMX=NX-1
      LIMY=NY-1
      TOLER=0.005*(SCALEX+SCALEY)
C
C     THE ACCURACY TOLERANCE FOR THE BENDER IS SET AT ONE-HUNDREDTH OF
C     THE AVERAGE OF THE SCALEX AND SCALEY VALUES. THIS SEEMS TO BE
C     ACCURATE ENOUGH - SOME SMOOTHING IS PERFORMED BY SRFIT.
C
      DO 20 JB=1,NY
      BX(1,JB)=DX*(-3.0*B(1,JB)+4.0*B(2,JB)-B(3,JB))
      DO 10 IB=2,LIMX
      BX(IB,JB)=DX*(B(IB+1,JB)-B(IB-1,JB))
   10 CONTINUE
      BX(NX,JB)=DX*(B(NX-2,JB)-4.0*B(NX-1,JB)+3.0*B(NX,JB))
   20 CONTINUE
      DO 40 IB=1,NX
      BY(IB,1)=DY*(-3.0*B(IB,1)+4.0*B(IB,2)-B(IB,3))
      DO 30 JB=2,LIMY
      BY(IB,JB)=DY*(B(IB,JB+1)-B(IB,JB-1))
   30 CONTINUE
      BY(IB,NY)=DY*(B(IB,NY-2)-4.0*B(IB,NY-1)+3.0*B(IB,NY))
   40 CONTINUE
C
C     COMPUTE THE X AND Y DIRECTION COSINES OF THE VECTORS NORMAL TO
C     SURFACE B AT ITS GRID POINTS. ARRAY BX(IB,JB) IS USED FOR THE
C     X DIRECTION COSINES AND ARRAY BY(IB,JB) IS USED FOR THE Y
C     DIRECTION COSINES.
C
      DO 60 IB=1,NX
      DO 50 JB=1,NY
      VECMAG=SQRT(BX(IB,JB)*BX(IB,JB)+BY(IB,JB)*BY(IB,JB)+1.0)
      BX(IB,JB)=BX(IB,JB)/VECMAG
      BY(IB,JB)=BY(IB,JB)/VECMAG
   50 CONTINUE
   60 CONTINUE
C
C     FOR EACH POINT ON SURFACE A, FIND THE NORMAL VECTORS ON SURFACE B
C     WHICH PASS THROUGH THAT POINT. EXTEND EACH OF THESE VECTORS FROM
C     SURFACE B TO SURFACE C, IN ORDER TO DETERMINE HOW FAR THE MEDIAN
C     PLANE HAS BEEN DISPLACED ALONG THAT VECTOR. ADD ALL OF THESE
C     DISPLACEMENTS TOGETHER AND DIVIDE BY THE NUMBER OF VECTORS FOUND,
C     IN ORDER TO COMPUTE THE DISPLACEMENT OF THAT POINT ON SURFACE A.
C
C     A = THE NAME OF THE ARRAY FOR THE OLD SURFACE WHICH IS TO BE BENT.
C     B = THE NAME OF THE ARRAY FOR THE NEW MEDIAN SURFACE.
C     C = THE NAME OF THE ARRAY FOR THE OLD MEDIAN SURFACE.
C     D = THE NAME OF THE ARRAY FOR THE NEW SURFACE, AFTER BENDING.
C
      NPTS=0
      DO 180 IA=1,NX
      DO 170 JA=1,NY
      SUMX=0.0
      SUMY=0.0
      SUMZ=0.0
```

```
      COUNT=0.0
      IBEG=MAX0(1,(IA-INFLUN))
      IEND=MIN0(LIMX,(IA+INFLUN))
      JBEG=MAX0(1,(JA-INFLUN))
      JEND=MIN0(LIMY,(JA+INFLUN))
C
C     FOR EACH SCALEX-BY-SCALEY REGION ON SURFACE B, DETERMINE WHETHER
C     IT IS POSSIBLE TO SELECT A NORMAL VECTOR FROM THE REGION WHICH
C     PASSES THROUGH THE POINT CURRENTLY BEING PROCESSED ON SURFACE A.
C
C     WE START BY GUESSING THAT THE DESIRED NORMAL VECTOR GOES THROUGH
C     THE CORNER OF THE REGION. WE THEN TRY TO REFINE THAT GUESS. IF IN
C     DOING SO WE MOVE THE NORMAL VECTORS STARTING LOCATION OUT OF THE
C     REGION, WE QUIT. OTHERWISE, WE QUIT WHEN WE HAVE EITHER FOUND THE
C     DESIRED VECTOR OR WHEN WE HAVE MOVED IT LESS THAN ONE-HUNDREDTH OF
C     THE GRID SPACINGS, IN ANY ITERATION. THE VECTOR IS (VX,VY,VZ).
C
      DO 140 IB=IBEG,IEND
      DO 130 JB=JBEG,JEND
      DX=0.0
      DY=0.0
   70 VX=SCALEX*(IA-IB-DX)
      VY=SCALEY*(JA-JB-DY)
C
C     THE FOLLOWING IS THE HARMONIC INTERPOLATION SCHEME.
C
      VZ=A(IA,JA)-((1-DX)*(1-DY)*B(IB,JB)+DX*(1-DY)*B(IB+1,JB)
     1    +DY*(1-DX)*B(IB,JB+1)+DX*DY*B(IB+1,JB+1))
      VMAG=SQRT(VX*VX+VY*VY+VZ*VZ)
      IF (VMAG.EQ.0.0) GO TO 72
      VX=VX/VMAG
      VY=VY/VMAG
      VZ=VZ/VMAG
      GO TO 74
   72 VX=0.0
      VY=0.0
      VZ=0.0
C
C     THE FOLLOWING IS THE HARMONIC INTERPOLATION SCHEME.
C
   74 VECX=(1-DX)*(1-DY)*BX(IB,JB)+DX*(1-DY)*BX(IB+1,JB)
     1    +DY*(1-DX)*BX(IB,JB+1)+DX*DY*BX(IB+1,JB+1)
      VECY=(1-DX)*(1-DY)*BY(IB,JB)+DX*(1-DY)*BY(IB+1,JB)
     1    +DY*(1-DX)*BY(IB,JB+1)+DX*DY*BY(IB+1,JB+1)
      VECZ=SQRT(1.0-VECX*VECX-VECY*VECY)
      COSANG=VECX*VX+VECY*VY+VECZ*VZ
      SINANG=SQRT(1.0-COSANG*COSANG)
C
C     MAKING THE SIMPLIFYING ASSUMPTION THAT A AND B ARE LEVEL SURFACES,
C
      DIST=VMAG*SINANG
      DVX=(VX-VECX)*SIGN(1.0,COSANG)
      DVY=(VY-VECY)*SIGN(1.0,COSANG)
      DVMAG=SQRT(DVX*DVX+DVY*DVY)
      IF (DVMAG.EQ.0.0) DVMAG=10.0E+50
      DVX=DVX/DVMAG
      DVY=DVY/DVMAG
      DX=DX+DIST*DVX/SCALEX
      DY=DY+DIST*DVY/SCALEY
C
C     NOTE THAT NO LOGIC IS INCLUDED FOR STEPPING OVER GRID LINE
C     BOUNDARIES, IN THE GENERAL SENSE. THE PROGRAM IS ALLOWED TO
C     WANDER ONE-QUARTER OF A GRID-LINE SPACING INTO ADJACENT GRID
C     SQUARES, IN ORDER TO ENSURE THAT DESIRED POINTS WHICH FALL EXACTLY
C     ON GRID LINES ARE FOUND. HOWEVER, IF THE PROGRAM INTRUDES FARTHER
C     THAN ONE-QUARTER OF THE GRID-LINE SPACING INTO AN ADJACENT GRID
```

```
C     SQUARE, THE SEARCH IS ENDED - THE DESIRED NORMAL VECTOR IS ABSENT.
C
      IF (DX.LT.-0.25) GO TO 120
      IF (DX.GT. 1.25) GO TO 120
      IF (DY.LT.-0.25) GO TO 120
      IF (DY.GT. 1.25) GO TO 120
      IF (DIST.GE.TOLER) GO TO 70
C
C     AT THIS POINT, A NORMAL VECTOR PASSING THROUGH THE DESIRED POINT
C     ON SURFACE A HAS BEEN FOUND. IT IS A UNIT VECTOR HAVING THE
C     COMPONENTS (VX,VY,VZ). IT PASSES THROUGH SURFACE B AT THE POINT
C     WHERE X=(IB-1+DX)*SCALEX AND Y=(JB-1+DY)*SCALEY. NEXT WE WILL FIND
C     THE POINT AT WHICH IT INTERSECTS SURFACE C. WE WILL FIRST GUESS
C     THAT IT INTERSECTS SURFACE C AT THE SAME COORDINATES AT WHICH IT
C     INTERSECTS SURFACE B. WE WILL THEN REFINE OUR GUESS.
C
      IC=IB
      JC=JB
      DXC=DX
      DYC=DY
      ZA=A(IA,JA)
   80 VECX=SCALEX*(IA-IC-DXC)
      VECY=SCALEY*(JA-JC-DYC)
C
C     THIS IS THE HARMONIC INTERPOLATION SCHEME.
C
      VECZ=ZA-((1-DXC)*(1-DYC)*C(IC,JC)+DXC*(1-DYC)*C(IC+1,JC)
     1        +DYC*(1-DXC)*C(IC,JC+1)+DXC*DYC*C(IC+1,JC+1))
      VECMAG=SQRT(VECX*VECX+VECY*VECY+VECZ*VECZ)
      IF (VECMAG.EQ.0.0) GO TO 82
      VECX=VECX/VECMAG
      VECY=VECY/VECMAG
      VECZ=VECZ/VECMAG
      GO TO 84
   82 VECX=0.0
      VECY=0.0
      VECZ=0.0
   84 COSANG=VECX*VX+VECY*VY+VECZ*VZ
      SINANG=SQRT(1.0-COSANG*COSANG)
C
C     MAKING THE SIMPLIFYING ASSUMPTION THAT C IS A LEVEL SURFACE,
C
      DIST=VECMAG*SINANG
      DVX=(VX-VECX)*SIGN(1.0,COSANG)
      DVY=(VY-VECY)*SIGN(1.0,COSANG)
      DVMAG=SQRT(DVX*DVX+DVY*DVY)
      IF (DVMAG.EQ.0.0) DVMAG=10.0E+50
      DVX=DVX/DVMAG
      DVY=DVY/DVMAG
C
C     THE VALUE OF DIST GIVES THE DISTANCE AT WHICH THE NEXT ITERATION
C     IS TO BEGIN. THE VALUES OF DVX AND DVY GIVE THE DIRECTION.
C
      DXCN=DXC+DIST*DVX/SCALEX
      DYCN=DYC+DIST*DVY/SCALEY
      IX=DXCN
      JY=DYCN
      DXCN=DXCN-IX
      DYCN=DYCN-JY
C
C     THIS IS THE LOGIC FOR STEPPING BACKWARD OVER GRID SQUARE EDGES.
C
      IF (DXCN.GE.0.0) GO TO 90
      DXCN=DXCN+1.0
      IX=IX-1
   90 IF (DYCN.GE.0.0) GO TO 100
```

```
      DYCN=DYCN+1.0
      JY=JY-1
C
C     THIS IS THE LOGIC FOR STEPPING FORWARD OVER GRID SQUARE EDGES.
C
  100 IC=IC+IX
      JC=JC+JY
      DXC=DXCN
      DYC=DYCN
      IF (IC.LT.1)        GO TO 120
      IF (IC.GT.NX)       GO TO 120
      IF (JC.LT.1)        GO TO 120
      IF (JC.GT.NY)       GO TO 120
      DISTX=(IB+DX-IC-DXC)*SCALEX
      DISTY=(JB+DY-JC-DYC)*SCALEY
      DISTZ=VZ*VMAG-VECZ*VECMAG*SIGN(1.0,COSANG)
      TEST=DIST/SQRT(DISTX*DISTX+DISTY*DISTY+DISTZ*DISTZ)
      IF (TEST.LT.0.01)   GO TO 110
      IF (DIST.GE.TOLER) GO TO 80
C
C     STORE DISPLACEMENT FROM SURFACE C TO SURFACE B ALONG (VX,VY,VZ).
C
  110 SUMX=SUMX+DISTX
      SUMY=SUMY+DISTY
      SUMZ=SUMZ+DISTZ
      COUNT=COUNT+1.0
  120 CONTINUE
  130 CONTINUE
  140 CONTINUE
      IF (COUNT.LE.0.0) GO TO 160
      NPTS=NPTS+1
      POINT(1,NPTS)=(IA-1)*SCALEX+SUMX/COUNT
      POINT(2,NPTS)=(JA-1)*SCALEY+SUMY/COUNT
      POINT(3,NPTS)=A(IA,JA)+(SUMZ/COUNT)
      IF (POINT(1,NPTS).LT.-SCALEX) GO TO 150
      IF (POINT(2,NPTS).LT.-SCALEY) GO TO 150
      IF (POINT(1,NPTS).GT.(NX+1)*SCALEX) GO TO 150
      IF (POINT(2,NPTS).LE.(NX+1)*SCALEY) GO TO 160
  150 NPTS=NPTS-1
  160 CONTINUE
  170 CONTINUE
  180 CONTINUE
C
C     WE HAVE NOW DISPLACED ALL OF THE GRID POINTS OF SURFACE A. WE HAVE
C     PLACED THE RESULTS IN THE POINT ARRAY. WE HAVE DISCARDED THE
C     RESULTS FOR GRID POINTS WHICH WERE DISPLACED MORE THAN ONE GRID
C     SPACING OFF OF THE SIDE OF THE GRID. WE MUST NOW DETERMINE THE
C     HEIGHT OF THIS DISTORTED SURFACE AT EACH GRID POINT. THE RESULTS
C     OF THIS COMPUTATION WILL BE PLACED IN THE D ARRAY.
C
  185 N=12
      IF (N.GT.NPTS) N=NPTS
      DO 310 I=1,NX
      X=(I-1)*SCALEX
      DO 300 J=1,NY
      Y=(J-1)*SCALEY
C
C     FIND THE N POINTS WHICH ARE CLOSEST TO THE GRID POINT (I,J).
C     STORE THEM IN ORDER OF CLOSENESS IN THE ARRAY NAMED CLOSE.
C
      DO 190 K=1,N
      CLOSE(K,4)=10.0E+50
  190 CONTINUE
      DO 250 K=1,NPTS
      DX=X-POINT(1,K)
      DY=Y-POINT(2,K)
```

```
      DISTSQ=DX*DX+DY*DY
      IF (DISTSQ.GE.CLOSE(N,4)) GO TO 240
      L=N-1
  200 IF (DISTSQ.GT.CLOSE(L,4)) GO TO 210
      L=L-1
      IF (L.GT.0) GO TO 200
  210 L=L+1
      NN=N
  220 IF (NN.LE.L) GO TO 230
      CLOSE(NN,1)=CLOSE(NN-1,1)
      CLOSE(NN,2)=CLOSE(NN-1,2)
      CLOSE(NN,3)=CLOSE(NN-1,3)
      CLOSE(NN,4)=CLOSE(NN-1,4)
      NN=NN-1
      GO TO 220
  230 CLOSE(L,1)=POINT(1,K)
      CLOSE(L,2)=POINT(2,K)
      CLOSE(L,3)=POINT(3,K)
      CLOSE(L,4)=DISTSQ
  240 CONTINUE
  250 CONTINUE
C
C     AFTER FITTING A SECOND-DEGREE POLYNOMIAL TO THE CLOSEST POINTS, WE
C     CALCULATE AND STORE THE HEIGHT OF THE SURFACE AT THE GRID POINT.
C
      NUMBER=8
  260 CALL SRFIT(2,NUMBER,CLOSE(1,1),CLOSE(1,2),CLOSE(1,3),Q,IFLAG)
      IF (IFLAG.LE.0) GO TO 290
      NUMBER=NUMBER+2
      IF (NUMBER.LE.N) GO TO 260
      PRINT 270, I,J,X,Y
  270 FORMAT (49H0ERROR AT STMT 270 OF BENDER - SRFIT CANNOT FIT A,
     1        18H VALUE TO POINT I=,I3,4H, J=,I3,15H, THAT IS EAST=,
     2        F10.1,8H, NORTH=,F10.1,7H, USING,/,1H0,26X,5HPOINT,
     3        7H NUMBER,5X,9HEAST OR X,4X,10HNORTH OR Y,4X,6HHEIGHT,
     4        5H OR Z,6X,6HDISTSQ,/,27X,12H------------,4X,
     5        10H----------,4X,10H----------,4X,11H-----------,4X,
     6        10H----------)
      DO 285 L=1,N
      PRINT 280, L,(CLOSE(L,K),K=1,4)
  280 FORMAT (30X,I4,9X,F10.1,4X,F10.1,4X,F11.1,4X,F10.1)
  285 CONTINUE
      Q(1)= -10.0E+50
  290 D(I,J)=Q(1)+Q(2)*X+Q(3)*Y+Q(4)*X*X+Q(5)*X*Y+Q(6)*Y*Y
  300 CONTINUE
  310 CONTINUE
      RETURN
C
C
C     THIS ENTRY POINT IS USED IN TILTING THE SURFACE (CALLED A), A
C     NUMBER OF DEGREES (DEG), IN A RIGHT-HANDED FASHION, AROUND A
C     HORIZONTAL VECTOR THROUGH THE POINT X=PTX,Y=PTY,Z=PTZ, WHICH
C     POINTS IN A DIRECTION PHI WHICH IS MEASURED IN DEGREES, IN A
C     COMPASS-LIKE FASHION FROM NORTH (OR EQUIVALENTLY, THE Y AXIS).
C
C     *****5500
C     ENTRY TILT(NX,NY,SCALEX,SCALEY,A,DEG,AXIS,D,PTX,PTY,PTZ)
C     *****
C     *****CDC6400
C     ENTRY TILT
      ENTRY TILT
C     DEG=B
C     AXIS=C
C     PTX=E
C     PTY=F
C     PTZ=G
```

```
C     *****
C
      GAMMA=DEG/57.2957795
      PHI=-AXIS/57.2957795
      SINPHI=SIN(PHI)
      COSPHI=COS(PHI)
      NPTS=0
      DO 410 I=1,NX
      DO 400 J=1,NY
      Y=(J-1)*SCALEY
      X=(I-1)*SCALEX
      NPTS=NPTS+1
      Z=A(I,J)-PTZ
      P= (X-PTX)*COSPHI+(Y-PTY)*SINPHI
      QQ=(PTX-X)*SINPHI+(Y-PTY)*COSPHI
      THETA=SIGN(1.57079633,Z)
C
C     (1.57079633 IS EQUAL TO PI OVER TWO)
C
      IF (P.NE.0.0) THETA=ATAN(Z/P)
      R=SQRT(Z*Z+P*P)
      PPRIME=R*COS(THETA-GAMMA)*SIGN(1.0,P)
      POINT(1,NPTS)=PPRIME*COSPHI-QQ*SINPHI+PTX
      POINT(2,NPTS)=PPRIME*SINPHI+QQ*COSPHI+PTY
      POINT(3,NPTS)=PPRIME*TAN(THETA-GAMMA)+PTZ
  400 CONTINUE
  410 CONTINUE
      GO TO 185
      END
      SUBROUTINE PAGER(N)
C
      COMMON /IOCOM/ NLINE,NPAGE
C
      DATA MARKER /1/
C
      IF (N+NLINE.LE.40) RETURN
      NPAGE=NPAGE+1
      IF (MARKER.EQ.1) GO TO 20
      PRINT 10
   10 FORMAT (1H0,25X,80H0         1         2         3         4
     A  5         6         7         8,/,26X,80H1234567890123456789012
     B4567890123456789012345678901234567890123456789012345678901234567890)
   20 PRINT 30,NPAGE
   30 FORMAT (1H1,50X,30HIMAGES OF CONTROL CARDS FOLLOW,43X,5HPAGE ,I3)
      PRINT 10
      NLINE=4
      MARKER=0
      RETURN
C
      ENTRY EPAGE
C
      IF (MARKER.EQ.1) RETURN
      PRINT 10
      MARKER=1
      RETURN
      END
      SUBROUTINE GRAPH(GRID,M,N,NPLOT)
C
C     THIS SUBROUTINE PRODUCES X - Y (THAT IS, EAST - NORTH) PLOTS OF
C     GEOLOGICAL SURFACES. IF THE SURFACES ARE MORE THAT TWELVE DATA
C     POINTS WIDE, IT PRINTS THEM OUT IN NORTH-TO-SOUTH STRIPS WHICH
C     ARE EACH NO MORE THAN TWELVE DATA POINTS WIDE, AND WHICH CAN
C     BE PLACED SIDE BY SIDE SO THAT THE WHOLE SURFACE CAN BE SEEN.
C     A SIMPLE FORM OF DATA-CONTROLLED FORMATTING IS USED.
C
      DIMENSION GRID(30,30),NLABEL(12)
```

```
C
      NSTRIP=1
      LOWM=1
      LIMM=MIN0(M,12)
   10 LIMI=LIMM-LOWM+1
      DO 20 I=1,LIMI
   20 NLABEL(I)=LOWM+I-1
      PRINT 30, NPLOT,NSTRIP
   30 FORMAT (22H1Z VALUES FOR SURFACE ,I1,26H - NORTH IS TOWARD THE TOP
     1          55H OF THE PAGE, EAST IS TOWARD THE RIGHT. (EAST = X OR I,
     2          23H NORTH = Y OR J) STRIP ,I1)
      DO 280 K=1,N
      J=N+1-K
      BIG=0.0
      DO 70 I=LOWM,LIMM
      SIZE=ABS(GRID(I,J))
      IF (SIZE-BIG) 60,60,50
   50 BIG=SIZE
   60 CONTINUE
   70 CONTINUE
      IF (BIG-1.0) 80,100,100
   80 PRINT 90,J,(GRID(I,J),I=LOWM,LIMM)
   90 FORMAT(/////,1X,I4,5X,12(F8.6,2X))
      GO TO 270
  100 IF (BIG-10.0) 110,130,130
  110 PRINT 120,J,(GRID(I,J),I=LOWM,LIMM)
  120 FORMAT (/////,1X,I4,5X,12(F8.5,2X))
      GO TO 270
  130 IF (BIG-100.0) 140,160,160
  140 PRINT 150,J,(GRID(I,J),I=LOWM,LIMM)
  150 FORMAT (/////,1X,I4,5X,12(F8.4,2X))
      GO TO 270
  160 IF (BIG-1000.0) 170,190,190
  170 PRINT 180,J,(GRID(I,J),I=LOWM,LIMM)
  180 FORMAT (/////,1X,I4,5X,12(F8.3,2X))
      GO TO 270
  190 IF (BIG-10000.0) 200,220,220
  200 PRINT 210,J,(GRID(I,J),I=LOWM,LIMM)
  210 FORMAT (/////,1X,I4,5X,12(F8.2,2X))
      GO TO 270
  220 IF (BIG-100000.0) 230,250,250
  230 PRINT 240,J,(GRID(I,J),I=LOWM,LIMM)
  240 FORMAT (/////,1X,I4,5X,12(F8.1,2X))
      GO TO 270
  250 PRINT 260,J,(GRID(I,J),I=LOWM,LIMM)
  260 FORMAT (/////,1X,I4,5X,12(F8.0,2X))
  270 CONTINUE
  280 CONTINUE
      PRINT 290, (NLABEL(I),I=1,LIMI)
  290 FORMAT (/////,11X,12(I4,6X))
      IF (M-LIMM) 310,310,300
  300 LOWM=LOWM+12
      NEWM=LOWM+11
      LIMM=MIN0(M,NEWM)
      NSTRIP=NSTRIP+1
      GO TO 10
```

```
  310 RETURN
      END
      SUBROUTINE RELAX(GRID,M,N,TOLER)
C
C     THIS SUBROUTINE RELAXES AN M BY N GRID OF DATA POINTS SO THAT
C     LAPLACES EQUATION IS SATISFIED WITH RESPECT TO THE BOUNDARY
C     POINT VALUES GIVEN. M IS THE COLUMN INDEX, N IS THE ROW INDEX.
C
      DIMENSION GRID(30,30)
C
C     FIRST, INITIALIZE THE GRID BY LINEAR APPROXIMATION.
C
      LIMM=M-1
      LIMN=N-1
      DO 20 I=2,LIMM
      DIFF=(GRID(I,N)-GRID(I,1))/LIMN
      DO 10 J=2,LIMN
      GRID(I,J)=GRID(I,1)+(J-1)*DIFF
   10 CONTINUE
   20 CONTINUE
      ITER=1
C
C     FOUR DIFFERENT RELAXATION PATTERNS ARE USED ALTERNATELY.
C     THIS SPEEDS UP ERROR PROPOGATION, AND THEREBY, CONVERGENCE.
C
   30 LOWM = 2
      LOWN = 2
      LIMM = M - 1
      LIMN = N - 1
      INCRM = 1
      INCRN = 1
      GO TO 70
   40 LOWM = M-1
      LOWN = 2
      LIMM = 2
      LIMN = N-1
      INCRM = -1
      INCRN = 1
      GO TO 110
   50 LOWM = M-1
      LOWN = N-1
      LIMM = 2
      LIMN = 2
      INCRM = -1
      INCRN = -1
      GO TO 70
   60 LOWM = 2
      LOWN = N - 1
      LIMM = M - 1
      LIMN = 2
      INCRM = 1
      INCRN = -1
      GO TO 110
C
C     J WITHIN I RELAXATION (INDICES CAN GO UP OR DOWN)
C
   70 BIGDIF=0.0
      I=LOWM
   80 J=LOWN
   90 TESTVAL=GRID(I,J)
      GRID(I,J)=0.25*(GRID(I+1,J)+GRID(I-1,J)+GRID(I,J+1)+GRID(I,J-1))
      CHANGE=ABS(TESTVAL-GRID(I,J))
      BIGDIF=AMAX1(CHANGE,BIGDIF)
      IF (J.EQ.LIMN) GO TO 100
```

```
      J=J+INCRN
      GO TO 90
  100 IF (I.EQ.LIMM) GO TO 150
      I=I+INCRM
      GO TO 80
C
C     I WITHIN J RELAXATION (INDICES CAN GO UP OR DOWN)
C
  110 BIGDIF=0.0
      J=LOWN
  120 I=LOWM
  130 TESTVAL=GRID(I,J)
      GRID(I,J)=0.25*(GRID(I+1,J)+GRID(I-1,J)+GRID(I,J+1)+GRID(I,J-1))
      CHANGE=ABS(TESTVAL-GRID(I,J))
      BIGDIF=AMAX1(CHANGE,BIGDIF)
      IF (I.EQ.LIMM) GO TO 140
      I=I+INCRM
      GO TO 130
  140 IF (J.EQ.LIMN) GO TO 150
      J=J+INCRN
      GO TO 120
C
C     CHECK FOR CONVERGENCE
C
  150 IF (BIGDIF-TOLER) 170,170,160
C
C     IF NOT WITHIN TOLERANCE, REPEAT RELAXATION USING NEXT PATTERN.
C
  160 ITER=ITER+1
      IF (ITER.GT.4) ITER=1
      GO TO (30,40,50,60),ITER
C
C     OTHERWISE, RETURN
  170 RETURN
      END
      SUBROUTINE SRFIT (NORD,M,X,Y,Z,A,IF)
      INTEGER FK,FJ
      DIMENSION A(50),B(50),F(50),X(50),Y(50),
     1          Z(50),PHI(50,50),BIN(50,50)
      IF=0
      DMIN=0.0001
      NOP=NORD+1
      N=NOP*(NOP+1)/2
      DO 240 JS=1,NOP
      DO 240 KS=1,JS
      I=JS*(JS-1)/2+KS
      DO 90 K=1,M
      XX=1.0
      YY=1.0
      IF (I-1) 250,80,10
   10 IF (I-3) 20,30,40
   20 XX=X(K)
      GO TO 80
   30 YY=Y(K)
      GO TO 80
   40 FK=JS-KS
      FJ=KS-1
      IF (FK) 60,60,50
   50 XX=X(K)**FK
   60 IF (FJ) 80,80,70
   70 YY=Y(K)**FJ
   80 CONTINUE
   90 F(K)=XX*YY
      A(I)=0.0
      C=0.0
      IF (I-1) 100,100,120
```

```
100 DO 110 J=1,M
110 D=D+F(J)*F(J)
    D=SQRT(D)
    GO TO 200
120 IM=I-1
    DO 150 K=1,IM
    T=0.0
    DO 130 J=1,M
130 T=T+F(J)*PHI(J,K)
    B(K)=T
    DO 140 J=1,M
140 F(J)=F(J)-T*PHI(J,K)
150 CONTINUE
    DO 160 J=1,M
160 D=D+F(J)*F(J)
    D=SQRT(D)
    IF (D-DMIN) 250,250,170
170 CONTINUE
    DO 190 K=1,IM
    T=0.0
    DO 180 J=K,IM
180 T=T-BIN(K,J)*B(J)
190 BIN(K,I)=T/D
200 CONTINUE
    BIN(I,I)=1.0/D
    DO 210 J=1,M
210 PHI(J,I)=F(J)/D
    T=0.0
    DO 220 K=1,M
220 T=T+PHI(K,I)*Z(K)
    DO 230 K=1,I
230 A(K)=A(K)+T*BIN(K,I)
240 CONTINUE
    RETURN
250 IF=1
    RETURN
    END
```

B. PROGRAM TUNNEL

```
      PROGRAM TUNNEL
C                                 READ GEOLOGY FILE, CREATE TUNNEL FILE
C
      COMMON /FPOLE/ XX,YY,ZZ,II,JJ,LL
      COMMON /GEOLFL/ NX,NY,SCALEX,SCALEY,INDEX(25),PROP(6,25)
      COMMON /NEWPT/ X1,Y1,Z1,X2,Y2,Z2,XM,YM,ZM,DL,LSEGNO
      COMMON /UPARM/ DIAM,XORIG,YORIG,UNIT,DELTA
C
      DIMENSION CARDIN(5)
      DATA CUMDL /0./
      DATA ICOUNT /0/
      DATA IFLAG /0/
      DATA INEND /0/
      DATA LFIN /0/
      DATA LSTLL /0/
      DATA SLNGTH /0./
      DATA CARDIN /5*0./
C                                 INITIALIZE
      DIAM = 10.
      XORIG = 1.
      YORIG = 1.
      UNIT = 1.
      DELTA = 20.
      LSEGNO = 0
      X1 = 0.
      Y1 = 0.
      Z1 = 0.
      X2 = 0.
      Y2 = 0.
      Z2 = 0.
      REWIND 50
      REWIND 40
C
C                                 READ GEOLOGY FILE
      CALL RDGEOL
C                                 READ PARAMETER CARDS
C
   80 IF (INEND .EQ. 1) GO TO 300
      READ 100, IKEY, (CARDIN(I),I=1,5)
  100 FORMAT (A6,4X,5(F10.4))
      ICOUNT = ICOUNT + 1
      IF (IKEY .EQ. 6HNEWLEG) GO TO 190
      IF (IKEY .EQ. 6HSTART ) GO TO 170
      IF (IKEY .EQ. 6HEND   ) GO TO 180
      IF (IKEY .EQ. 6HOPTION) GO TO 150
      PRINT 110, IKEY
  110 FORMAT (39H0ERROR - INVALID KEYWORD ON INPUT CARD ,A6 )
      GO TO 400
C                                 OPTION CARD READ
  150 IF (ICOUNT .EQ. 1) GO TO 160
      PRINT 155
  155 FORMAT (47H0ERROR - OPTION CARD, IF PRESENT, MUST BE FIRST )
      GO TO 400
  160 IF (CARDIN(1) .GT. 0.) DIAM = CARDIN(1)
      XORIG = CARDIN(2)
      YORIG = CARDIN(3)
      IF (CARDIN(4) .GT. 0.) UNIT = CARDIN(4)
      IF (CARDIN(5) .GT. 0.) DELTA = CARDIN(5)
      GO TO 80
C                                 START CARD READ
  170 PRINT 172, DIAM,XORIG,YORIG,UNIT,DELTA
  172 FORMAT (26H1TUNNEL OPTIONS -      DIAM,9X,5HXORIG,11X,5HYORIG,10X,
     *    4HUNIT,8X,5HDELTA/17X,F10.3,2X,2(F14.3,2X),2(F10.3,2X)//
```

```
     *   56HOTUNNEL FILE -    POSITION      PROPERTY 1      PROPERTY 2 ,
     *   5X,55HPROPERTY 3     PROPERTY 4      PROPERTY 5      PROPERTY 6,
     *   3X,4HFLAG /)
      X1 = CARDIN(1)
      Y1 = CARDIN(2)
      Z1 = CARDIN(3)
      GO TO 80
C                              END CARD FEAD
  180 INEND = 1
C                              NEWLEG CARD READ
  190 X2 = CARDIN(1)
      Y2 = CARDIN(2)
      Z2 = CARDIN(3)
      LSEGNO = LSEGNO + 1
C
C                              PROCESS TUNNEL LEG BETWEEN (X1,Y1,Z1)
C                                   AND (X2,Y2,Z2)
      XWRK = (X2-X1)*(X2-X1)+(Y2-Y1)*(Y2-Y1)+(Z2-Z1)*(Z2-Z1)
      SLNGTH = SQRT (XWRK)
      DL = 0.
      IF (LSEGNO .GT. 1) GO TO 250
C                              FINO LAYER OF BEGINNING POINT
      XX = X1
      YY = Y1
      ZZ = Z1
      CALL GETLYR
      LSTLL = LL
C
C                              TEST POINTS ALONG TUNNEL MIDLINE IN
C                                   INCREMENTS OF DELTA FT.
  250 DL = DL + DELTA
      IF (DL .GT. SLNGTH) DL = SLNGTH
      CALL NEWPNT
      XX = XM
      YY = YM
      ZZ = ZM
      CALL GETLYR
      IF (DL .LT. SLNGTH) GO TO 260
      LFIN = LSEGNO
      GO TO 270
  260 IF (LSTLL .EQ. LL) GO TO 250
C                              NEW LAYER ENCOUNTERED
  270 DDL = DL + CUMDL
      LPROP = INDEX(LSTLL)
      PRINT 275,DDL, (PROP(I,LPROP),I=1,6),IFLAG
  275 FORMAT (11X,7(F14.4,1X),2X,I4)
  277 IROPTEM=PROP(2,LPROP)
      WRITE(40,280) DDL,PROP(1,LPROP),IROPTEM,(PROP(I,LPROP),I=3,6),IFLA
     1G
  280 FORMAT(2E18.10,I5,4E18.10,I5)
      IF (DDL .LT. 0.) GO TO 310
      LSTLL = LL
      IF (LFIN .LT. LSEGNO) GO TO 250
C
C                              ENO OF TUNNEL SEGMENT HAS BEEN REACHED
      X1 = X2
      Y1 = Y2
      Z1 = Z2
      CUMDL = CUMDL + DL
      GO TO 80
C                              END OF JOB
  300 DDL = -100.
      GO TO 277
  310 PRINT 320
  320 FORMAT (27HOTUNNEL TERMINATED NORMALLY )
```

```
  400 CALL EXIT
      END
      SUBROUTINE GETLYR
C
C     PURPOSE - FIND LAYER (LL) IN WHICH THE POINT
C               (XX,YY,ZZ) IS LOCATED
C
      COMMON /FPOLE/ XX,YY,ZZ,II,JJ,LL
      COMMON /GEOLFL/ NX,NY,SCALEX,SCALEY,INDEX(25),PROP(6,25)
      COMMON /UPARM/ DIAM,XORIG,YORIG,UNIT,DELTA
      COMMON /ZSAVE/ ZSTOR (30,30,25),LFLAG(25)
      DIMENSION ZHOLD(25)
      DATA ZHOLD /25*0./
      DATA LHOLD /0/
C
      LHOLD = 0
      DO 120 J = 1,25
      ZHOLD(J) = -10.0 E51
  120 CONTINUE
C                                FIND I INTERVAL FOR XX
      XCOOR = 1 + (XX-XORIG) / (SCALEX*UNIT)
      ILOW = XCOOR
      IHI = ILOW + 1
C                                FIND J INTERVAL FOR YY
      YCOOR = 1 + (YY -YORIG) / (SCALEY * UNIT)
      JLOW = YCOOR
      JHI = JLOW + 1
C                                SEE IF POINT IS OUTSIDE I J GRID
      IF (ILOW .LT. 1) GO TO 700
      IF (IHI .GT. NX) GO TO 730
      IF (JLOW .LT. 1) GO TO 750
      IF (JHI .GT. NY) GO TO 760
C                                EXAMINE THE 4 (I,J) POLES SURROUNDING
C                                       (XX,YY,ZZ) FOR LAYER(S) INVOLVED
      II = ILOW
      JJ = JLOW
      CALL FINDL
      LHOLD = LL
C
      JJ = JHI
      CALL FINDL
      IF (LHOLD - LL) 310,240,310
C
  240 II = IHI
      CALL FINDL
      IF (LHOLD - LL) 310,280,310
C
  280 JJ = JLOW
      CALL FINDL
      IF (LHOLD - LL) 310,950,310
C
C                                INTERPOLATION REQUIRED
  310 XA = ILOW
      YA = JLOW
      XB = IHI
      YB = JLOW
      XC1 = ILOW
      XC = XCOOR
      YC = JHI
      DO 500 J=1,25
      IF (LFLAG(J) .EQ. 0) GO TO 500
      LYR = J
      ZA = ZSTOR (ILOW,JLOW,LYR)
      ZB = ZSTOR(IHI,JLOW,LYR)
      ZC1 = ZSTOR(ILOW,JHI,LYR)
      ZC2 = ZSTOR (IHI,JHI,LYR)
```

```
C                              FIND POINT ON LINE BETWEEN (ILOW,JHI,ZC1)
C                                   AND (IHI,JHI,ZC2) WHICH IS AT XX
      ZC = (XCOOR - XC1) * (ZC2 - ZC1) + ZC1
C                              DERIVE EQUATION OF PLANE DEFINED BY
C                                (XA,YA,ZA),(XB,YB,ZB),(XC,YC,ZC)
      A = YA*ZB+YC*ZA+YB*ZC-YC*ZB-YB*ZA-YA*ZC
      B = ZA*XB+ZC*XA+ZB*XC-ZC*XB-ZB*XA-ZA*XC
      C = XA*YB+XC*YA+XB*YC-XC*YB-XB*YA-XA*YC
      D = XA*YB*ZC+YA*ZB*XC+ZA*XB*YC-ZA*YB*XC-YA*XB*ZC-XA*ZB*YC
C                              STORE Z FOR PLANE AT POINT (XX,YY)
      ZHOLD(J) = D - B*YCOOR - A*XCOOR / C
  500 CONTINUE
C                              FIND LOWEST ZHOLD(J) S.T. ZHOLD(J) GT ZZ
  510 ZLOW = 999999.
      LL = 0
      DO 550 J=1,25
      IF (LFLAG(J) .EQ. 0) GO TO 550
      TESTZ = ZHOLD(J)
      IF (TESTZ .LT. ZZ) GO TO 550
      IF (TESTZ .GT. ZLOW) GO TO 550
      ZLOW = TESTZ
      LL = J
  550 CONTINUE
      IF (LL .GT. 0) GO TO 950
      PRINT 570, XX,YY,ZZ
  570 FORMAT (34H0ERROR - NO LAYER FOUND FOR POINT ,3(F14.3,1X) )
      GO TO 900
C
C     ****************************************************************
C
C                              POINT WEST OF GRID
  700 II = 1
  702 IF (JHI .GT. NY) GO TO 740
      IF (JLOW .LT. 1) GO TO 745
      JJ = JLOW
      CALL FINDL
      LHOLD = LL
      JJ = JHI
      CALL FINDL
      IF (LL .EQ. LHOLD) GO TO 950
      DO 705 J=1,25
      IF (LFLAG(J) .EQ. 0) GO TO 705
      ZC1 = ZSTOR(II,JLOW,J)
      ZC2 = ZSTOR(II,JHI,J)
      ZHOLD(J) = (YCOOR - JLOW) * (ZC2-ZC1) + ZC1
  705 CONTINUE
      GO TO 510
C                              POINT EAST OF GRID
  730 II = NX
      GO TO 702
C                              POINT NW OR NE OF GRID
  740 JJ = NY
      GO TO 790
C                              POINT SW OR SE OF GRID
  745 JJ = 1
      GO TO 790
C                              POINT SOUTH OF GRID
  750 JJ = 1
  752 IF (IHI .GT. NX) GO TO 770
      IF (ILOW .LT. 1) GO TO 775
      II = ILOW
      CALL FINDL
      LHOLD = LL
      II = IHI
      CALL FINDL
      IF (LL .EQ. LHOLD) GO TO 950
```

```
      DO 755 J=1,25
      IF (LFLAG(J) .EQ. 0) GO TO 755
      ZC1 = ZSTOR(ILOW,JJ,J)
      ZC2 = ZSTOR(IHI,JJ,J)
      ZHOLD(J) = (XCOOR - ILOW) * (ZC2 - ZC1) + ZC1
  755 CONTINUE
      GO TO 510
C                                POINT NORTH OF GRID
  760 JJ = NY
      GO TO 752
C                                POINT NE OF GRID
  770 II = NX
      GO TO 790
C                                POINT NW OF GRID
  775 II = 1
  790 CALL FINDL
      GO TO 950
C
C     ************************************************************
C
  900 CONTINUE
      CALL EXIT
  950 CONTINUE
      RETURN
      END
      SUBROUTINE NEWPNT
C
C     PURPOSE - GIVEN ENDPOINTS (X1,Y1,Z1) AND (X2,Y2,Z2) OF LINE,
C                 FIND (XM,YM,ZM) WHICH IS DL FT. FROM (X1,Y1,Z1) ON LINE
C     TECHNIQUE-EXPRESS YM AND ZM IN TERMS OF XM, USING 2-POINT FORM
C                 OF STRAIGHT-LINE EQUATION.
C               SUBSTITUTE IN FORMULA FOR DISTANCE BETWEEN 2 POINTS,
C                 (X1,Y1,Z1) AND (XM,YM=F(XM),ZM=G(XM)),
C                 AND SOLVE FOR XM.
C               RECONSTRUCT YM AND ZM FROM XM.
C               SPECIAL CASES EXIST IF XDIF,YDIF, OR ZDIF ARE ZERO,
C                 THUS REDUCING PROBLEM TO 1 OR 2 DIMENSIONS.
C     NOTE     - IF DL IS GT LENGTH OF SEGMENT, ROUTINE WILL ABORT.
C
      COMMON /NEWPT/ X1,Y1,Z1,X2,Y2,Z2,XM,YM,ZM,DL,LSEGNO
      DATA LSTSEG /0/
      DATA MCODE /0/
      DATA IBRNCH /0/
      DATA XDIF,YDIF,ZDIF,A,B,T1,T2 /7*0./
C
      NROOT = 0
      XM = 0.
      YM = 0.
      ZM = 0.
      IF (LSEGNO .EQ. LSTSEG) GO TO 30
C     ************************************************************
C                              INITIALIZE FOR NEW LINE SEGMENT
      MCODE = 0
      XDIF = X2 - X1
      YDIF = Y2 - Y1
      ZDIF = Z2 - Z1
      IF (XDIF .EQ. 0.) MCODE = 1
      IF (YDIF .EQ. 0.) MCODE = MCODE + 10
      IF (ZDIF .EQ. 0.) MCODE = MCODE + 100
C     ************************************************************
C                              BRANCH ACCORDING TO CASE INVOLVED
   30 IF (MCODE .EQ. 0  ) GO TO 80
      IF (MCODE .EQ. 11 ) GO TO 600
      IF (MCODE .EQ. 101) GO TO 625
      IF (MCODE .EQ. 110) GO TO 650
      IF (MCODE .EQ. 1  ) GO TO 675
```

```
      IF (MCODE .EQ. 10 ) GO TO 700
      IF (MCODE .EQ. 100) GO TO 725
      PRINT 50
   50 FORMAT (28HOERROR - ENOPOINTS IDENTICAL)
      GO TO 880
C     ******************************************************************
C                                   NORMAL CASE (XDIF,YOIF,ZOIF NON-ZERO)
   80 IBRNCH = 1
      IF (LSEGNO .EQ. LSTSEG) GO TO 110
C                             SET UP COEFFICIENTS OF QUAORATIC EQUATION
      A = 1.+ (YDIF * YDIF + ZOIF * ZDIF) / (XOIF * XOIF)
      B = -2. * A * X1
      T1 = X1
      T2 = X2
      GO TO 100
C                             RECONSTRUCT YM ANO ZM
   90 XM = RT
      XFRAC = (XM - X1) / XOIF
      YM = Y1 + (YDIF * XFRAC)
      ZM = Z1 + (ZDIF * XFRAC)
      GO TO 750
C     ******************************************************************
C     ******************************************************************
C                             SOLVE OUADRATIC EOUATION
  100 IF (A .EQ. 0.) GO TO 450
  110 ARG = 4. * A * DL * DL
C                             TEST FOR EXISTENCE OF REAL ROOT(S)
      IF (ARG .GE. 0.) GO TO 300
      PRINT 200, A,B,ARG
  200 FORMAT (36HOERROR - ARG IN NEWPNT NEGATIVE. A= ,F14.3,4H B= ,
     *     F14.3,6H ARG= ,F14.3)
      GO TO 880
C                             FIND ROOTS OF OUADRATIC
  300 ARGP = SQRT(ARG)
      DEN = 2. * A
      IF (DEN .EQ. 0. )GO TO 450
      RT = (-B + ARGR) / DEN
C                             SELECT ROOT ON GIVEN SEGMENT OF LINE
  400 IF (T1 .LE. RT .AND. RT .LE. T2) GO TO 500
      IF (T2 .LE. RT .AND. RT .LE. T1) GO TO 500
      NROOT = NROOT + 1
      IF (NROOT .EQ. 2) GO TO 450
      RT = (-B - ARGR) / DEN
      GO TO 400
  450 PRINT 470, A, B, ARG
  470 FORMAT (51HOERROR - NEWPNT FOUNO NO ROOT ON GIVEN SEGMENT. A= ,
     *       F14.3,4H B= ,F14.3,6H ARG= ,F14.3)
      GO TO 880
  500 GO TO ( 90,680,705,730),IBRNCH
C     ******************************************************************
C     ******************************************************************
C                                       SPECIAL CASES
C                             XDIF ANO YOIF ARE ZERO
  600 YM = Y1
      XM = X1
      IF (ZDIF) 610,605,605
  605 ZM = Z1 + DL
      GO TO 750
  610 ZM = Z1-DL
      GO TO 750
C                             XDIF ANO ZOIF ARE ZERO
  625 XM = X1
      ZM = Z1
      IF (YDIF) 635,630,630
  630 YM = Y1 + DL
      GO TO 750
```

```
  635 YM = Y1 - DL
      GO TO 750
C                                   YDIF AND ZDIF ARE ZERO
  650 YM = Y1
      ZM = Z1
      IF (XDIF) 660,655,655
  655 XM = X1 + DL
      GO TO 750
  660 XM = X1 - DL
      GO TO 750
C                                   ONLY XDIF IS ZERO
  675 IBRNCH = 2
      IF (LSTSEG .EQ. LSEGNO) GO TO 110
      A = 1.+ (YDIF*YDIF)/(ZDIF*ZDIF)
  678 B = -2.*A *Z1
      T1 = Z1
      T2 = Z2
      GO TO 100
  680 XM = X1
      ZM = RT
      YM = Y1 + (ZM - Z1) * YDIF / ZDIF
      GO TO 750
C                                   ONLY YDIF IS ZERO
  700 IBRNCH = 3
      IF (LSTSEG .EQ. LSEGNO) GO TO 110
      A = 1.+ (XDIF*XDIF)/(ZDIF*ZDIF)
      GO TO 678
  705 YM = Y1
      ZM = RT
      XM = X1 + (ZM-Z1) * XDIF/ZDIF
      GO TO 750
C                                   ONLY ZDIF IS ZERO
  725 IBRNCH = 4
      IF (LSEGNO .EQ. LSTSEG) GO TO 110
      A = 1. + (YDIF*YDIF) / (XDIF*XDIF)
      B = -2 * A * X1
      T1 = X1
      T2 = X2
      GO TO 100
  730 ZM = Z1
      XM = RT
      YM = Y1 + (XM-X1) * YDIF/XDIF
C     ******************************************************************
C                                   CHECK RANGE OF RESULTING POINT
  750 IF (X1 .LE. XM .AND. XM .LE. X2) GO TO 760
      IF (X2 .LE. XM .AND. XM .LE. X1) GO TO 760
      GO TO 850
  760 IF (Y1 .LE. YM .AND.YM .LE. Y2) GO TO 770
      IF (Y2 .LE. YM .AND.YM .LE. Y1) GO TO 770
      GO TO 850
  770 IF (Z1 .LE. ZM .AND. ZM .LE. Z2) GO TO 999
      IF (Z2 .LE. ZM .AND. ZM .LE. Z1) GO TO 999
C     ******************************************************************
  850 PRINT 870, XM,YM,ZM
  870 FORMAT (48H0ERROR - POINT GIVEN BY NEWPNT NOT ON LINE. XM= ,
     *        F14.3,5H YM= ,F14.3,5H ZM= ,F14.3)
  880 CALL EXIT
  999 LSTSEG = LSEGNO
      RETURN
      END
      SUBROUTINE ROGEOL
C
C     ENTRY ROGEOL READS AND STORES ALL GEOLOGY FILE DATA
C
C     ENTRY FINDL DETERMINES WHAT LAYER (LL) INCLUDES POSITION ZZ
C               AT POLE (II,JJ)
```

```
C
      COMMON /FPOLE/ XX,YY,ZZ,II,JJ,LL
      COMMON /GEOLFL/ NX,NY,SCALEX,SCALEY,INDEX(25),PROP(6,25)
      COMMON /ZSAVE/ ZSTOR (30,30,25),LFLAG(25)
C
      DIMENSION HOLD(27)
C
      DO 30 I = 1,25
      LFLAG(I) = 0
   30 CONTINUE
      READ (50,60) NX,NY,SCALEX,SCALEY,(INDEX(ILAYR),ILAYR=1,25),
     *        ((PROP(I,IROCK),I=1,6),IROCK=1,25)
   60 FORMAT (2I5,2(E18.10),25I2,(E18.10))
      LIM = NX * NY
      DO 200 K = 1,LIM
      READ (50,80) (HOLD(L),L=1,27)
   80 FORMAT ((E18.10))
      I = HOLD(1)
      J = HOLD(2)
      DO 150 IZ = 1,25
      ZSTOR(I,J,IZ) = HOLD(IZ+2)
  150 CONTINUE
      IF (K .GT. 1) GO TO 200
      DO 170 IY = 1,25
      IF (HOLD(IY+2) .GT. -10.0 E51) LFLAG(IY) = 1
  170 CONTINUE
  200 CONTINUE
      RETURN
C
      ENTRY FINDL
C                                  FIND LOWEST HOLDZ(K) FOR WHICH
C                                       HOLDZ(K) GE ZZ
      ZLOW = 999999.
      LL = 0
  600 DO 700 K = 1,25
      IF (LFLAG(K) .EQ. 0) GO TO 700
      TESTZ = ZSTOR (II,JJ,K)
      IF (TESTZ .LT. ZZ) GO TO 700
      IF (TESTZ .GT. ZLOW) GO TO 700
      ZLOW = TESTZ
      LL = K
  700 CONTINUE
      IF (LL .GT. 0) GO TO 800
      PRINT 720, XX,YY,ZZ
  720 FORMAT (14H0ERROR - POINT ,3(F14.3,2X),12HABOVE GROUND)
      CALL EXIT
  800 LSTII = II
      LSTJJ = JJ
      RETURN
      END
```

C. PROGRAM GENTNL

```
      PROGRAM GENTNL
C
C     THIS PROGRAM GENERATES A TUNNEL FILE USING CARD INPUT ONLY,
C           BYPASSING GEOLOGY FILE REQUIREMENT
C
      DIMENSION CD(8)
      DATA OPOS /-10./
C
      REWIND 40
      PRINT 4005
 4005 FORMAT(///,20X,33H GEOLOGY PARAMETERS FOR TUNNEL              )
      PRINT 4006
 4006 FORMAT(//,5X,105H THIS GEOLOGY   UNCONFINED    ABRASIVENESS    ROC
     1K QUALITY        IN SITU        AMBIENT       WATER INFLOW         )
      PRINT 4007
 4007 FORMAT(2X,105H CEASES AT(FEET)  COMPRESSIVE                        DES
     1IGNATION      TEMPERATURE       RATE                                )
      PRINT 4008
 4008 FORMAT(5X,105H                  STRENGTH(PSI)
     1             (LB/FT**3)        (FT)          (GAL/MIN)
     1                                 )
C
  100 READ 110, (CD(I),I=1,8)
  110 FORMAT (8F10.4)
      CD(2)=CD(2)/1000.
      IF (CD(1) .LT. 0. .OR.  CD(1) .GT. OPOS) GO TO 140
      PRINT 120, CD(1)
  120 FORMAT (34H0ERROR - CARD SPECIFYING POSITION ,F10.4,
     *       16H OUT OF SEQUENCE)
      CALL EXIT
C
  140 IFLAG = CD(8)
      IA=CD(3)
      OPOS = CD(1)
      WRITE(40,210) (CD(I),I=1,2),IA,(CD(J),J=4,7),IFLAG
  210 FORMAT(2E18.10,I5,4E18.10,I5)
      IF (CD(1) .LT. 0.) GO TO 900
      PRINT 250, (CD(I),I=1,7),IFLAG
  250 FORMAT ( 3X,7(F14.4,1X),2X,I4)
      GO TO 100
C
  900 PRINT 910
  910 FORMAT (43H0TUNNEL FILE GENERATION TERMINATED NORMALLY )
      REWIND 40
      CALL EXIT
      END
```

D. PROGRAM CONTROL

```
GOLETA FORTRAN I.3 * AUTO REL * (07-12-72)                                                    07/25/72

                    PROGRAM CONTPL                                                   CONTRL     2
000003              COMMON /WHFELS/ AF,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,OF,DF,DTAS  WHEELS     2
                   I,  OTMA,DTU,FL,FC,FR,FT,HPA,HPEA,HPEV,HPFA,HPFV,HPV,LOCO,MC,ML   WHEELS     3
                   2,  NCAPS,NPOINT,NTD,NTM,NTMAX,XP,NTMILP,NTMLPP,NTRACK,SL         WHEELS     4
                   3,  TCURVX(20),TCURVY(20),TMAINT,TWE,VD,VS,VE,VF,VMAX,WC,WL,XDS   WHEELS     5
                   4,  MAXLD,NUMLD,LOUE,QUC,WUC,STATUS(36),WHY(24),MLTYP,WMR,ECONEQ, WHEELS     6
                   5   ECONSS,ELOCO,EMUCKC,ETRACK,ESWITC,EUNLOA,ERMAIN,IIBORE,       WHEELS     7
                   6   ISW(25),NTINIT,TCCV,TMCV                                      WHEELS     8
000003              COMMON /OLDCOM/ IFILD,KSTOP(25),KUNLO,LSTOP,LVEHCL,NBYBY,NSWCH   WHEELS     9
                   I,  NTRDA,NVFHCL,NUMSWT,SWITCH(20),TFC(25),TOP(25),TSTAT(25,4)    WHEELS    10
                   2,  UTIME(25),LOADR,MUKOT,XGS,IEXCA,MGS(5),MCV,MFLAGC,OUMMY(20)   WHEELS    11
000003              COMMON /NEWCOM/ LIFILO,LKSTOP(25),LKUNLO,LLSTOP,LLVHCL,LNBYBY    WHEELS    12
                   1,  LNSWCH,LNTRDA,LNVHCL,LNMSWT,FSWTCH(20),FTFC(25),FTOP(25)      WHEELS    13
                   2,  FTSTAT(25,4),FUTIME(25),LLOADR,LMUKOT,FXGS,LIEXCA,LMGS(5)     WHEELS    14
                   3,  LMCV,LMFLAC,FOUMMY(19)                                        WHEELS    15
000003              DIMENSION COMOLO(260),COMNEW(260),LTSTAT(25,4),ITSTAT(25,4)      WHEELS    16
000003              EOUIVALENCE (NVEHCL,NTRAIN,NTRUCK),(LVEHCL,LTRAIN,LTRUCK)        WHEELS    17
                   1,   (COMOLD,IFILD),(COMNEW,LIFILD,IFILLO),(NTDA,LNTROA)          WHEELS    18
                   2,   (FTSTAT,LTSTAT),(TSTAT,ITSTAT)                               WHEELS    19
                   3,   (LLVHCL,LLTRAN,LLTRUK),(LNVHCL,LNTRAN,LNTRUK)                WHEELS    20
000003              COMMON /BORING/ CL(3),CPC,OTA,OTC,DTCD,OTO,OTM,KK,PBM,R(100),RC  BORING     2
                   A, RPM,TR,XCPC, MASSEM,MBM,MBORE,MCD,MDISAS,LNCHNG,LNCUTR,NCUT(20) BORING    3
                   B,  WEAR(100),EBORFQ,ETRANS                                       BORING     4
000003              COMMON /BLAST / ADB,AOH,AH,CBIT,CBURN,CCAP,CEX,CM,CPL,CSTEEL     BLAST      2
                   B, LO,LOB,LBIT,LBURN,LSTEEL, MEN,ND,NOB,NH,NHB,PF,POB,POD,TCHG    BLAST      3
                   C, TIN,TOUT,TYPEPF,WPL,JUMIN,JUMOUT,NORILB,NDRILL                 BLAST      4
000003              COMMON /CONVEY/    ACM,DTBS,OWM,EF,FL,HP,QC,SMIN,WBI             BELTS      2
                   1,  WP,XLF,NSURGE,OF,OP,SM,DTCB,DTMB,AB,VBI,NEXON,NGEO,XF,LNSURG,
                   2   STIME,ODMB,DTMI,DTMO,FLM
000003              COMMON /ALL    / XI,SIR,IA,RQD,CS,TAMB,FLOW,IFLAG                ALL        2
                   1,  AT,O,E,SK,T,DT,X,PP,XMAX,TMAX,DX,OV,TPRINT,OTPRNT,IMOVE,JMETH ALL        3
                   2,  TSHFT,REPORT,OPPCT,TO,XO,XOISCH,ICHNG,XCHNG,TCHNG             ALL        4
000003              EOUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)                          ALL        5
000003              COMMON/MONEY/ JMMHM,OJM,OJMMH,OJMRO,DJMBMM,DMAINT,DJMBM,DJMGS    ALL        6
                   I,  PMGS,JMCV,OJMEC,ROPLAN,HPLANT,GSPLAN                          ALL        7
                   2,  ECPLAN,ROTIME,HTIME(2),GSTIME,ECTIME                          ALL        8
000003              COMMON/PERFRM/ RDUTIM,RDOTIM,UMHTIM,DMHTIM,GSUTIM,GSOTIM,ECUTIM  ALL        9
                   1,  ECOTIM,GOAY,GADV,GENO,GBEG                                    ALL       10
000003              COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2)   ALL       11
000003              REAL JMMHM,LD,LOB,LBIT,LBURN,LSTEEL,JMCV                         ALL       12
000003              DIMENSION G(8)                                                   ALL       13
000003              EOUIVALENCE (G,XT),(XE,XOE),(PR,PC)                              ALL       14
000003              COMMON /GRNO/ PSST(60,9),MAXPSST, UCS,UCSC,RATERB,RATESC,RATESS  SUPPORT    2
                   1,  GSLOS,IAS,IST,ERBORI,ESCPLA,GOOW,GSETOO,MAXPSS                SUPPORT    3
000003              COMMON /ENVC/ MAXMEN,TOTHP,QM,QD,VAMIN,VAMAX,QG(10),             ENVIRON    2
                   I   TA,TD,WA,FKD,FKT,CPA,CKA,REFRAT,AMC(10),ODR,EVENTP,CPUMP      ENVIRON    3
000003              DIMENSION JSTOP(25)                                              CONTRL    10
000003              EOUIVALENCE (JSTOP,LKSTOP)                                       CONTRL    11
000003              DATA (STATUS=6HSTOPPE,6HD, EMP,2HTY, 6HSTOPPE,6HD, FUL,1HL,      CONTRL    12
                   1 6HACCEL,,6H EMPTY,1H , 6HACCEL,,5H FULL,1H , 6HFULL S,6HPEED, , CONTRL    13
                   2  SHEMPTY, 6HFULL S, 6HPEED, , 4HFULL, 6HOECEL,,5HEMPTY, IH ,    CONTRL    14
                   3  6HOECEL,,5H FULL, 1H ,    6HIN SWI, 6HTCH, E, 4HMPTY,          CONTRL    15
                   4  6HIN SWI,6HTCH, F,3HULL, 6HIN DIS,6HCHARGE,5H AREA, 6HIN MAI,  CONTRL    16
                   6  6HNTENAN,2HCE)                                                 CONTRL    17
                   7,  (WHY=6HAT FAC,6HE, LOA,4HDING, 6HTRAIN ,5HAHEAO,1H ,          CONTRL    18
```

```
              8  6HTRAIN .6HCOMING.1H , 6HEXTERN.6HAL REA.4HSONS.
              9  6HWAITIN.6HG TO U.5HNLOAD, 6HWAITIN.6HG TO L.3HOAD,
              A  6HAT FAC.6HE, IN , 5HQUEUE, 3*6H......)
000003          DATA (COSTS=30*0.),(DX=0.),(DV=0.),(LOADR=0.),(MBORE=0),(MBM=0)
              I,  (LNCUTR=0),(RATMAX=0),(IDLE=0),(NOTIDL=0)
000003          DATA INIX/0/
           C**
           C
           C       INITIALIZATION ONLY
           C
           C**
000003          CALL INPUT
000004          CALL BORE
000005          CALL CUTTER
000006          CALL REPAIR
000007          CALL CVLOAD
000010          CALL CVMNT
000011          CALL RAILHL
000012          CALL RAILEX
000013          CALL RAILDS
000014          CALL RAILMT
000015          CALL GRNSUP
000016          CALL GSMAIN
000017          CALL ENVIR
000020          CALL REPORR
000021          CALL MAXADV
000022          CALL REPORC
000023          CALL INPUT2
000024          DO 310 II=1,260
000026          COMNEW(II)=COMOLD(II)
000030      310 CONTINUE
           C***
000032          PRINT 410
000036      410 FORMAT (1H1)
000036          TPRINT=T+DTPRNT
000040          CALL OUTPUT
000041      400 CONTINUE
           C***
           C
           C    START LOOP ON DT
           C
           C***
000041      401 XTEMP=X-XDISCH
000043          IF(XTEMP .LE. XT) GO TO 405
           C***
           C
           C    READ NEW GEOLOGY
           C
           C***
000046          READ(40,402)  G
000053          ICHNG=1
000054          TCHNG=(T-T0)/24.
000057          XCHNG=X-XDISCH
000061          IF(EOF,40) 600,404
000064      402 FORMAT(2E18.10,I5,4E18.10,I5)
```

```
000064     404 GO TO 401
         C***
         C
         C   ROCK DISINTEGRATION
         C
         C***
000065     405 CONTINUE
000065     420 CALL BORER
000066         CALL MAINT
000067         CALL CUTCHG
000070         CALL RAILTR
000071     406 CALL RAILOS
000072         CALL RAILXT
000073         CALL RAILMT
000074         CALL LOADCV
000075         CALL CVRPR
000076         CALL GROUN
000077         CALL GSMNT
000100         CALL ENVIRC
         C**
         C
         C     UPDATING X,T, AND FLAGS
         C
         C**
000101         T=T+DT
000103         X=X+DX
000105         DO 446 II=1,260
000107         COMOLD(II)=COMNEW(II)
000111     446 CONTINUE
000113         IF (MBM.EQ.0) GOTO 480
000114         MBORE=1
000115         GOTO 492
000116     480 IF (MBORE.EQ.1) MBORE=0
000121         IF (LNCUTR.EQ.0) GOTO 482
000122         MBORE=2
000123         GOTO 492
000124     482 IF (MBORE.EQ.2) MBORE=0
000127         IF (NBYBY.EQ.0)  GOTO 484
000130         MBORE=3
000131         GOTO 492
000132     484 IF (MBORE.EQ.3) MBORE=0
000135         IF (NSWCH-1) 490,488,486
000140     486 MBORE=5
000141         GOTO 492
000142     488 MBORE=4
000143         GO TO 492
000144     490 IF (MBORE.EQ.4 .OR. MBORE.EQ.5) MBORE=0
000154     492 IF(LOADR .EQ. 0) GO TO 494
000155         NUQU=NUQU+1
000157         GO TO 500
000157     494 IF(MBORE .NE. 6) GO TO 496
000161         MBORE=0
000162         NUQU=0
000162         GOTO 530
000163     496 NUQU=0
```

```
000164          GO TO 530
000165      500 IF ((MBORE.EQ.3).OR.(MBORE.EQ.4).OR.(MBORE.EQ.5)) GOTO 530
000201          IF(LVEHCL .GT. 0) GO TO 530
        C
        C        TRAIN QUEUE IS CHECKED TO MOVE ANOTHER TRAIN INTO THE LOADING ARE
        C        TRAIN STATUS IS CHANGED ON ALL TRAINS AFFECTED BY QUEUECHANGE
        C
000204          LLTR=0
000204          DO 515 ITR=1,NTRAIN
000206          IF ((ITSTAT(ITR,1).NE.0).OR.(JSTOP(ITR).LE.100)) GOTO 515
000217          KSTOP(ITR)=JSTOP(ITR)-1
000221          JSTOP(ITR)=KSTOP(ITR)
000223          LLTR=LLTR+1
000225          IF (JSTOP(ITR).NE.100) GOTO 515
000230           KSTOP(ITR)=)
000231      515 CONTINUE
000234          NUMLO=LLTR
000235          LOUE=LLTR*100
000237          IF (NUMLO.EQ.0) MBORE=6
000241      530 CONTINUE
000241          IF(NUQU .GE. 2) MBORE=6
000245          IF (IFXCA.EQ.0) GOTO 531
000246          IF (MBORE.EQ.0) MBORE=7
000250          GOTO 532
000251      531 IF (MBORE.EQ.7) MBORE=0
000254      532 CONTINUE
000254          IF(MCV .EQ. 0) GO TO 540
000255          IF (MBORE.EQ.0) MBORE=8
000257          GOTO 542
000260      540 IF (MBORE.EQ.8) MBORE=0
000263      542 CONTINUE
000263          ITBORE=MBORE
        C        PRINT OUTPUT REPORTS
000265      460 IF(T .LT. TPRINT) GO TO 461
000270          CALL OUTPUT
000271          TPRINT=TPRINT+DTPRNT
000273      461 IREPORT=REPORT*100
000277          IT=T*100+)
000304          LK=MOD(IT,2400)
000310          IF(LK .NE. 0) GO TO 462
000311          CALL MAXAOW
000312      462 LK=MOD(IT,IREPORT)
000316          IF(LK .NE. 0) GO TO 470
000317          CALL REPORS
000320          CALL REPORO
000321      470 CONTINUE
000321          IF(DX .NE. 0.) GO TO 471
000322          INIX=INIX+1
        C**
        C
        C        SHOULD SIMULATION BE ENDED BECAUSE NO ADVANCE FOR 5 DAYS
        C
        C**
000324          IF(INIX .GT. 720) GO TO 605
000327          GO TO 472
```

```
000327     471 INIX=0
000330     472 CONTINUE
000330         IF (T.LT.TMAX .AND. X.LT.XMAX) GOTO 400
        C**
        C
        C      ENDING SIMULATION
        C
        C**
000341     473 CALL OUTPUT
000342         CALL REPORS
000343         CALL REPORD
000344         RETURN
000346     600 PRINT 601
000352     601 FORMAT (24H0 GEOLOGY FILE EXHAUSTED)
000352         RETURN
000354     605 PRINT 474
000360     474 FORMAT(//,1X,40H SIMULATION ENDED-NO ADVANCE FOR 5 DAYS
000360                                                                )
000362         END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
NTRUCK
LTRAIN
LTRUCK
IFILD
LIFILD
IFILLD
LNTRDA
LLTRAN
LLTRUK
LNTRAN
LNTRUK
IMOVE
JMETH
XOE
PC
NVEHCL
NTDA
LLVHCL
LNVHCL
JMOVE
IMETH
XE
PR
```

E. SUBROUTINE INPUT

```
GOLETA FORTRAN 1.3 * AUTO RFL * (07-12-72)                                                07/25/72

                  SUBROUTINE INPUT                                              INPUT      2
          C***                                                                  INPUT      3
000002            COMMON /WHEELS/ AE,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,DE,DF,DTAS  WHEELS     2
                 1,  DTMA,DTU,FL,FC,FR,FT,HPA,HPFA,HPEV,HPFA,HPFV,HPV,LOCO,MC,ML   WHFELS     3
                 2,  NCAPS,NPOINT,NTD,NTM,NTMAX,XP,NTMILP,NTMLPP,NTRACK,SL        WHFELS     4
                 3,  TCURVX(20),TCURVY(20),TMAINT,TWE,VD,VS,VE,VF,VMAX,WC,WL,XDS   WHFELS     5
                 4,  MAXLD,NUMLD,LQUE,QUC,WUC,STATUS(36),WHY(24),MLTYP,WMR,ECONEQ, WHFELS     6
                 5   ECONSS,ELOCO,EMUCKC,ETRACK,ESWITC,EUNLOA,ERMAIN,IIBORE,      WHEELS     7
                 6   ISW(25),NTINIT,TCCV,TMCV                                     WHFELS     8
000002            COMMON /OLDCOM/ IFILD,KSTOP(25),KUNLO,LSTOP,LVEHCL,NBYBY,NSWCH  WHFELS     9
                 1,  NTRDA,NVFHCL,NUMSWT,SWITCH(20),TFC(25),TOP(25),TSTAT(25,4)   WHFELS    10
                 2,  UTIMF(25),LOADR,MUKOT,XGS,IFXCA,MGS(5),MCV,MFLAGC,DUMMY(20)  WHEELS    11
000002            COMMON /NEWCOM/ LIFILD,LKSTOP(25),LKUNLO,LLSTOP,LLVHCL,LNBYBY    WHFELS    12
                 1,  LNSWCH,LNTRDA,LNVHCL,LNMSWT,FSWTCH(20),FTFC(25),FTOP(25)     WHEELS    13
                 2,  FTSTAT(25,4),FUTIME(25),LLOADR,LMUKDT,FXGS,LIEXCA,LMGS(5)    WHEELS    14
                 3,  LMCV,LMFLAC,FDUMMY(19)                                       WHEELS    15
000002            DIMENSION COMOLD(260),COMNEW(260),LTSTAT(25,4),ITSTAT(25,4)     WHFELS    16
000002            EQUIVALENCE (NVEHCL,NTRAIN,NTRUCK),(LVEHCL,LTRAIN,LTRUCK)       WHFFLS    17
                 1,  (COMOLO,IFILD),(COMNEW,LIFILO,IFILLO),(NTDA,LNTRDA)          WHEELS    18
                 2,  (FTSTAT,LTSTAT),(TSTAT,ITSTAT)                               WHEELS    19
                 3,  (LLVHCL,LLTRAN,LLTRUK),(LNVHCL,LNTRAN,LNTRUK)                WHEELS    20
000002            COMMON /BORING/ CL(3),CPC,DTA,DTC,DTCD,DTD,DTM,KK,PBM,R(100),RC BORING     2
                 A, RPM,TR,XCPC, MASSEM,MBM,MBORE,MCD,MDISAS,LNCHNG,LNCUTR,NCUT(20) BORING   3
                 B,  WEAR(100),EBOREQ,ETRANS                                      BORING     4
000002            COMMON /CONVEY/    ACM,DTBS,DWM,EE,FL,HP,QC,SMIN,WBI            BELTS      2
                 1,  WB,XLF,NSURGE,DF,DP,SM,DTCP,DTMB,AB,VBI,NEXON,NGEO,XF,LNSURG,            1
                 2   STIME,DDMB,DTMI,DTMO,FLM                                                 2
000002            COMMON /BLAST / ADB,ADH,AH,CBIT,CBURN,CCAP,CEX,CM,CPL,CSTEEL    BLAST      2
                 B, LD,LDB,LBIT,LBURN,LSTEEL, MEN,ND,NDB,NH,NHB,PE,POB,POD,TCHG   BLAST      3
                 C, TIN,TOUT,TYPEPF,WPL,JUMIN,JUMOUT,NDRILB,NORILL                BLAST      4
000002            COMMON /ALL   / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG                ALL        2
                 1,  AT,D,E,SK,T,DT,X,PR,XMAX,TMAX,DX,DV,TPRINT,DTPRNT,IMDVE,JMETH ALL       3
                 2,  TSHFT,REPORT,OPPCT,TO,XO,XDISCH,ICHNG,XCHNG,TCHNG            ALL        4
000002            EQUIVALENCE (JMOVF,IMOVE),(IMETH,JMFTH)                         ALL        5
000002            COMMON/MONEY/ JMMHM,OJM,DJMMH,DJMRD,DJMBMM,DMAINT,DJMBM,DJMGS   ALL        6
                 1,  PMGS,JMCV,DJMEC,RDPLAN,HPLANT,GSPLAN                         ALL        7
                 2,  ECPLAN,RDTIME,HTIME(2),GSTIME,ECTIME                         ALL        8
000002            COMMON/PERFRM/ RDUTIM,ROOTIM,UMHTIM,DMHTIM,GSUTIM,GSDTIM,ECUTIM ALL        9
                 1,  ECDTIM,GDAY,GADV,GEND,GBEG                                   ALL       10
000002            COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2)  ALL       11
000002            REAL JMMHM,LD,LDB,LBIT,LBURN,LSTEEL,JMCV                        ALL       12
000002            DIMENSION G(9)                                                  ALL       13
000002            EQUIVALENCE (G,XT),(XE,XOE),(PR,PC)                             ALL       14
000002            COMMON /GRND/ PSST(60,9),MAXPSST, UCS,UCSC,RATERB,RATESC,RATESS SUPPORT    2
                 1,  GSLOS,IAS,IST,FRBORI,ESCPLA,GOOW,GSETDO,MAXPSS               SUPPORT    3
000002            COMMON /ENVC/ MAXMEN,TOTHP,QM,OO,VAMIN,VAMAX,OG(10),            ENVIRON    2
                 1   TA,TO,WA,FKO,FKT,CPA,CKA,REFRAT,AMC(10),ODR,EVENTP,CPUMP     ENVIRON    3
          C***                                                                  INPUT     11
000002            DIMENSION IMAGE(14),METHOD(10),MOVER(10)                        INPUT     12
000002            DATA (METHOD(I),I=1,10)/4HBORE,5HBLAST,3HJET,6HPELLET,6*5HDUMMY/ INPUT     13
000002            DATA (MOVER(J),J=1,10)/ 5HRAILS, 6HTRUCKS, 5HBELTS, 7*5HDUMMY/  INPUT     14
000002            DATA (PI=3.14159265358 98)                                      INPUT     15
000002            DIMENSION ISTA(25),TPOS(25),TSPD(25),TMAIN(25)                  INPUT     16
000002            DIMENSION BOMEN(10),BOCST(10),RAMEN(10),RACST(10),CVMEN(10),    INPUT     17
                 1  CVCST(10),GMEN(10),GCST(10),VCMEN(10),VCCST(10)               INPUT     18
```

```
000002        NAMELIST /BORE  /
             1    CL,CPC,DTA,DTC,DTCD,DTD,DTH,KK,PBM,R,RC,RPM,TR,XCPC
             2,EBOREQ,ETRANS,DJMBMM,BOMEN,BOCST
000002        NAMELIST /BLAST /
             1  Z
000002        NAMELIST /JET   /
             1  Z
000002        NAMELIST /PELLET/
             1  Z
000002        NAMELIST /RAILS /
             1    AE,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,DE,DF,DTAS,DTMA,DTU
             A,   NSWCH,NGEO,NEXON,XDE,AB,VBI,SM
             2,   EL,FC,FR,FT,HPA,HPEV,HPEA,HPEV,HPFA,HPEV,HPV,LOCO,MC,ML
             3,   NCARS,NPOINT,NTD,NTM,NTMAX,XP,NTMILP,NTMLPP,NTRACK,SL
             4,   TCURVX,TCURVY,TMAINT,TWE,VD,VS,VE,VF,VMAX,WC,WL,XDS,MAXLD
             5,   NVEHCL,NUMSWT,SWITCH,ISTA,TPOS,TSPD,TMAIN,KSTOP,MLTYP,WMR
             6,   ELOCO,EMUCKC,ETRACK,ESWITC,EUNLDA,ERMAIN,JMMHM,NUMLD,ISW
             7,   RAMEN,RACST
000002        NAMELIST /TRUCKS/
             1    AE,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,DE,DF,DTAS,DTMA,DTU
             A,   NSWCH,NGEO,NEXON,XDE,AB,VBI
             2,   EL,FC,FR,FT,HPA,HPEV,HPEA,HPEV,HPFA,HPEV,HPV,LOCO,MC,ML
             3,   NCARS,NPOINT,NTD,NTM,NTMAX,XP,NTMILP,NTMLPP,NTRACK,SL
             4,   TCURVX,TCURVY,TMAINT,TWE,VD,VS,VE,VF,VMAX,WC,WL,XDS,MAXLD
             5,   NVEHCL,NUMSWT,SWITCH,ISTA,TPOS,TSPD,TMAIN,KSTOP,MLTYP,WMR
             6,   ELOCO,EMUCKC,ETRACK,ESWITC,EUNLDA,ERMAIN,JMMHM,NUMLD,ISW
             7,   TRMEN,TRCST
000002        NAMELIST /BELTS /
             1  Z
000002        NAMELIST /GENERL/
             1    D,DT,X,XMAX,T,TMAX,DTPRNT,SK,PR,OPPCT,REPORT,XDISCH,E
000002        NAMELIST/GROUND/
             1  UCS,UCSC,RATERB,RATESC,RATESS,MAXPSS,ERBORI,ESCPLA,DJMGS
             2,   GDOW,GSETDO,GMEN,GCST
000002        NAMELIST/LOADER/
             1    AB,VBI,SM,TCCV,TMCV,WMR,MLTYP,ECONEQ,ECONSS,JMCV
             2,   CVMEN,CVCST
000002        NAMELIST/ENVIRC/
             1    EVENTP,MAXMEN,TOTHP,TA
             1,   QM,QD,VAMIN,VAMAX,TD,WA,CPA,CKA,REFRAT,AMC,VCMEN,VCCST,CPUMP
             2,   FKT
000002        EQUIVALENCE(BOMEN(1),BOMEN(1,1))
000002        EQUIVALENCE(BOCST(1),BOMEN(1,2))
000002        EQUIVALENCE(VCMEN(1),ECMEN(1,1))
000002        EQUIVALENCE(VCCST(1),ECMEN(1,2))
000002        EQUIVALENCE(RAMEN(1),HMEN(1,1,1))
000002        EQUIVALENCE(RACST(1),HMEN(1,2,1))
000002        EQUIVALENCE(CVMEN(1),HMEN(1,1,2))
000002        EQUIVALENCE(CVCST(1),HMEN(1,2,2))
000002        EQUIVALENCE(GMEN(1),GSMEN(1,1))
000002        EQUIVALENCE(GCST(1),GSMEN(1,2))
          C***
000002        EFUNC(X)=1.8*EXP(.084*X)
          C
          C   THE FIRST SECTION OF SUBROUTINE INPUT
```

```
              C   COPIES CARD-IMAGES FROM FILE4 (CARD READER)
              C   ONTO FILE5 (INPUT FILE FOR REMAINDER OF PROGRAM)
              C   AND FILE6 (OUTPUT FILE FOR THE PROGRAM)
              C
              C***
000013              LINE = 0
              C***
              C
              C   CDC 6000 FORTRAN
              C
              C***
000014            1 READ (4,10) IMAGE
000022              IF (EOF,4) 3,2
              C***
              C
              C   B5500 FORTRAN
              C
              C   1 READ (4,10,END=3) IMAGE
              C
              C***
000025           10 FORMAT (13A6,A2)
000025            2 WRITE (5,10) IMAGE
000033              IF (MOD(LINE,40).EQ.0) WRITE (6,11)
000043           11 FORMAT (1H1, 9X14HCARD-IMAGES.../)
000043              IF (MOD(LINE,10).EQ.0) WRITE (6,12) (K, K=5,80,5)
000060           12 FORMAT (1H0, 19X16I5/ 14X6HCARD  ,  8(10H....*....*))
000060              LINE = LINE+1
000062              WRITE (6,13) LINE, IMAGE
000071           13 FORMAT (I18, 2X13A6, A2)
000071              GOTO 1
000072            3 ENDFILE 5
000074              REWIND 5
              C***
              C
              C   READ FRAGMENTATION AND REMOVAL METHODS
              C
              C***
000076              READ (5,21) M,N
000106           21 FORMAT (A6, 4XA6)
000106              DO 30 I=1,10
000110              IF (M.EQ.METHOD(I)) GOTO 31
000112           30 CONTINUE
000114              WRITE (6,36) M
000121           36 FORMAT (1H0, 9X21HFRAGMENTATION METHOD , A6,
                   1  36H CANNOT BE SIMULATED AT THIS TIME...,
                   2  31HJOB ABORTED BY SUBROUTINE INPUT)
000121              I = 0
000122           31 DO 32 J=1,10
000124              IF (N.EQ.MOVER(J)) GOTO 33
000126           32 CONTINUE
000130           37 FORMAT (1H0, 9X16HMUCK REMOVAL BY , A6,
                   1  36H CANNOT BE SIMULATED AT THIS TIME...,
                   2  31HJOB ABORTED BY SUBROUTINE INPUT)
000130              J = 0
000131           33 IF (I.EQ.0 .OR. J.EQ.0) STOP
```

```
000141         IMETH = I
000143         JMOVE = J
000144         READ (5,GENERL)
000147         WRITE (6,GENERL)
000152         GOTO (110,120,130,140), IMETH
000162     110 READ (5,BORE  )
000165         WRITE (6,BORE  )
000170         GOTO 205
000171     120 READ (5,BLAST )
000174         WRITE (6,BLAST )
000177         GOTO 205
000200     130 READ (5,JET   )
000203         WRITE (6,JET   )
000206         GOTO 205
000207     140 READ (5,PELLET)
000212         WRITE (6,PELLET)
000215     205 GOTO (210,220,230), JMOVE
000224     210 READ (5,RAILS)
000227         WRITE (6,RAILS )
000232         GOTO 305
000233     220 READ (5,TRUCKS)
000236         WRITE (6,TRUCKS)
000241         GOTO 305
000242     230 READ (5,BELTS )
000245         WRITE (6,BELTS )
000250     305 CONTINUE
000250         READ(5,LOADER)
000253         WRITE (6,LOADER)
000256         READ(5,GROUND)
000261         WRITE(6,GROUND)
000264         READ (5,ENVIRC)
000267         WRITE (6,ENVIRC)
000272         REWIND 40
000274         READ(40,402) G
000302         ICHNG=1
000303         TCHNG=T/24.
000305         XCHNG=X-XDISCH
000307     402 FORMAT(2E18.10,I5,4E18.10,I5)
000307         AT = PI*D*D/4.0
000312         PRINT 403
000316     403 FORMAT(1H1)
000316         PRINT 404, AT
000324     404 FORMAT (25H0  TUNNEL CROSS SECTION = F 10.4, 6H SQ FT)
000324         LVEHCL=0
000325         DO 306 I=1,25
000327         ITSTAT(I,1)=ISTA(I)
000331          TSTAT(I,2)=TPOS(I)
000334          TSTAT(I,3)=TSPD(I)
000336          TSTAT(I,4)=TMAIN(I)
000340         IF (ISTA(I).EQ.0 .AND. KSTOP(I).EQ.1) LVEHCL=I
000350     306 CONTINUE
000352         IF(MAXPSS .EQ. 0) GO TO 325
000353         DO 320 I=1,MAXPSS
000355         READ(5,322) (PSST(I,K),K=1,9)
000370     322 FORMAT(9F8.2)
```

```
000370     320 CONTINUE
000373     325 CONTINUE
000373         XO=X
000375         TO=T
000376         NTINIT=NVEHCL
000400         RETURN
         C
000400         ENTRY INPUT2
000405         PRINT 78
000411      78 FORMAT(1HI)
000411         PRINT 77
000415      77 FORMAT (50H0   INPUT DATA AFTER INITIALIZATION BY SUBROUTINES)
000415         WRITE(6,GENERL)
000420         GOTO (501,502,503,504),IMETH
000430     501 WRITE (6,BORF)
000433         GOTO 505
000434     502 WRITE (6,BLAST)
000437         GOTO 505
000440     503 WRITE (6,JET)
000443         GOTO 505
000444     504 WRITE (6,PELLET)
000447     505 GOTO (5II,512,5I3), JMOVE
000456     5II WRITE (6,RAILS)
000461         GOTO 520
000462     512 WRITE (6,TRUCKS)
000465         GOTO 520
000466     513 WRITE (6,BELTS)
000471     520 WRITE (6,GROUND)
000474         WRITE(6,LOADER)
000477         WRITE(6,ENVIRC)
000502         RETURN
000503         END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
NTRAIN
NTRUCK
LTRAIN
LTRUCK
IFILO
LIFILO
IFILLO
LNTPDA
LLTRAN
LLTRUK
LNTRAN
LNTRUK
IMOVE
JMETH
XT
FC
NTDA
LLVHCL
LNVHCL
XE
```

F. SUBROUTINE OUTPUT

```
GOLETA FORTRAN I.3 * AUTO RFL * (07-12-72)                                        07/25/72

            SUBROUTINE OUTPUT                                                      OUTPUT     2
000002      COMMON /WHEELS/ AE,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,OE,DF,DTAS        WHEELS     2
           I,  OTMA,DTU,FL,F",FR,FT,HPA,HPFA,HPFV,HPFA,HPFV,HPV,LOCO,MC,ML         WHEELS     3
           2,  NCARS,NPOINT,NTD,NTM,NTMAX,XP,NTMILP,NTMLPP,NTRACK,SL               WHEELS     4
           3,  TCURVX(20),TCURVY(20),TMAINT,TWE,VD,VS,VE,VF,VMAX,WC,WL,XOS         WHEELS     5
           4,  MAXLD,NUMLO,LQUE,QUC,WUC,STATUS(36),WHY(24),MLTYP,WMR,ECONEQ,       WHEELS     6
           5   ECONSS,FLOCO,FHUCKC,ETRACK,ESWITC,EUNLOA,ERMAIN,IIBORF,             WHEELS     7
           6   ISW(25),NTINIT,TCCV,TMCV                                            WHEELS     8
000002      COMMON /OLDCOM/ IFILD,KSTOP(25),KUNLO,LSTOP,LVEHCL,NAYBY,NSWCH         WHEELS     9
           I,  NTRDA,NVEHCL,NUMSWT,SWITCH(20),TFC(25),TOP(25),TSTAT(25,4)          WHEELS    10
           2,  UTIME(25),LOADR,MUKOT,XGS,IFXCA,MGS(5),MCV,MFLAGC,OUMMY(20)         WHEELS    11
000002      COMMON /NEWCOM/ LIFILD,LKSTOP(25),LKUNLO,LLSTOP,LLVHCL,LNBYBY          WHEELS    12
           I,  LNSWCH,LNTROA,LNVHCL,LNMSWT,FSWTCH(20),FTFC(25),FTOP(25)            WHEELS    13
           2,  FTSTAT(25,4),FUTIME(25),LLOADR,LMUKOT,FXGS,LIFXCA,LMGS(5)           WHEELS    14
           3,  LMCV,LMFLAC,FOUMMY(19)                                              WHEELS    15
000002      OIMENSION COMOLD(260),COMNEW(260),LTSTAT(25,4),ITSTAT(25,4)            WHEELS    16
000002      EQUIVALENCE (NVEHCL,NTRAIN,NTRUCK),(LVEHCL,LTRAIN,LTRUCK)              WHEELS    17
           I,   (COMOLD,IFILD),(COMNEW,LIFILD,IFILLO),(NTDA,LNTRDA)                WHEELS    18
           2,   (FTSTAT,LTSTAT),(TSTAT,ITSTAT)                                     WHEELS    19
           3,   (LLVHCL,LLTRAN,LLTRUK),(LNVHCL,LNTRAN,LNTRUK)                      WHEELS    20
000002      COMMON /BORING/ CL(3),CPC,DTA,DTC,DTCO,OTD,OTM,KK,PBM,R(I00),RC        BORING     2
           A,  RPM,TR,XCPC, MASSEM,MBM,MBORF,MCD,MDISAS,LNCHNG,LNCUTR,NCUT(20)     BORING     3
           B,  WEAR(I00),EBORFQ,ETRANS                                             BORING     4
000002      COMMON /ALL   / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG                       ALL        2
           1,  AT,D,E,SK,T,DT,X,PR,XMAX,TMAX,DX,DV,TPRINT,DTPRNT,IMOVE,JMETH       ALL        3
           2,  TSHFT,REPORT,OPPCT,TO,XO,XDISCH,ICHNG,XCHNG,TCHNG                   ALL        4
000002      EQUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)                                ALL        5
000002      COMMON/MONEY/ JMMHM,DJM,OJMMH,DJMRO,OJMBMM,DMAINT,DJMBM,OJMGS          ALL        6
           I,  PMGS,JMCV,DJMEC,RDPLAN,HPLANT,GSPLAN                                ALL        7
           2,  ECPLAN,RDTIME,HTIME(2),GSTIME,ECTIME                                ALL        8
000002      COMMON/PERFRM/ RDUTIM,RODTIM,UMHTIM,OMHTIM,GSUTIM,GSDTIM,ECUTIM        ALL        9
           I,  ECDTIM,GDAY,GADV,GENO,GBEG                                          ALL       10
000002      COMMON/LABOR/ RDMEN(I0,2),HMEN(I0,2,2),GSMEN(I0,2),ECMEN(I0,2)         ALL       11
000002      REAL JMMHM,LD,LDB,LBIT,LBURN,LSTEEL,JMCV                               ALL       12
000002      OIMENSION G(8)                                                         ALL       13
000002      EQUIVALENCE (G,XT),(XE,XDE),(PR,PC)                                    ALL       14
000002      DIMENSION IVAL(20)                                                     TEST       2
000002      COMMON/TEST/VALUE(30),NAME(30)                                         TEST       3
           I,IHEAD(II0),JHEAD(I00)                                                 TEST       4
000002      EQUIVALENCE (IVAL,VALUE)                                               TEST       5
000002      OATA (NAME=2HT=, 2HX=, 3HIA=, 4HSTR=, 3HDX=, 4HMBM=, 7HLNCUTR=,        OUTPUT     7
           I  6HNBYBY=, 6HNSWCH=, 6HMBORE=, 6HLOADR=, 7HNUMSWT=,                   OUTPUT     8
           2  6HIEXCA=,4HMCV=,7HMFLAGC=,7HIEXCAV=,7HMGS(2)=                        OUTPUT     9
           7   ,7HMGS(3)=,7HMGS(4)=,4HXGS=,5HPMGS=,4HQDR=,8*1H ),(NNAME=22)        OUTPUT    10
      C***                                                                         OUTPUT    11
      C                                                                            OUTPUT    12
      C   OUTPUT FOR TEST CASE                                                     OUTPUT    13
      C                                                                            OUTPUT    14
      C***                                                                         OUTPUT    15
000002      VALUE(I)=T                                                             OUTPUT    16
000004      VALUE(2)=X-XDISCH                                                      OUTPUT    17
000006      IVAL(3)=IA                                                             OUTPUT    18
000007      VALUE(4)=STR                                                           OUTPUT    19
000011      VALUE(5)=DX                                                            OUTPUT    20
000012      IVAL(6)=MBM                                                            OUTPUT    21
```

```
000014        IVAL(7)=LNCUTR
000015        IVAL(8)=NBYBY
000017        IVAL(9)=NSWCH
000020        IVAL(10)=MBORE
000022        IVAL(11)=LOADR
000023        IVAL(12)=NUMSWT
000025        IVAL(13)=IEXCA
000026        IVAL(14)=MCV
000030        IVAL(15)=MFLAGC
000031        IVAL(16)=NUMLD
000033        IVAL(17)=MGS(2)
000034        IVAL(18)=MGS(3)
000036        IVAL(19)=MGS(4)
000037        VALUE(20)=XGS-XDISCH
000041        VALUE(21)=PMG5
000043        VALUE(22)=QDR
000044        PRINT 5
000050      5 FORMAT(///,1X,16H WORKING STORAGE    )
000050        PRINT 411, (NAME(I),VALUE(I),I=I,NNAME)
000065    411 FORMAT (//2(3XA7,E10.3),3XA7,I4,2(3XA7,E10.3),3XA7,I4/
            1  9(3XA7,I4)/  4(3XA7,I4),3(3XA7,E10.3))
000065        PRINT 412, (WEAR(K),K=1,KK)
000100    412 FORMAT (16H0 CUTTER WEAR...  / (10F10.3))
000100        IF (LNCUTR.NE.1) GOTO 420
000102        PRINT 413, (NCUT(I),I=I,LNCHNG)
000115    413 FORMAT (26H0 CUTTERS BEING CHANGED...  /(10I10))
000115    420 CONTINUE
000115    104 DO 108 I=1,NVEHCL
000117        IS=ITSTAT(I,I)
000121        KS=IS*3+1
000123        MS=KS+2
000125        JS=KSTOP(I)
000127        LS=JS*3-2
000130        IF (JS.GT.100) LS=19
000133        IF (JS.EQ.0) LS=22
000135        NS =LS+2
000137        TTT=TSTAT(I,2)-XDISCH
000142        PRINT 105,    I, (STATUS(K),K=KS,MS),(WHY(L),L=LS,NS)
            1,TTT,(TSTAT(I,J),J=3,4),I5,J5
000203    105 FORMAT    (11H  TRAIN NO. I2, 4H...., 3A6, 2X3A6,
            1 4H X = E11.4, 8H FT  V = E11.4, 12H MPH  DSH =    F7.4, 2I5)
000203    108 CONTINUE
000206        RETURN
000206        END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
NTRAIN
NTRUCK
LTRAIN
LTRUCK
IFILD
LIFILD
IFILLD
LNTRDA
LLTRAN
LLTRUK
```

```
LNTRAN
LNTRUK
IMOVE
JMETH
XT
XDE
PC
LVEHCL
NTDA
LLVHCL
LNVHCL
JMOVE
IMETH
XE
PR
```

G. SUBROUTINE BORE

GOLETA FORTRAN I.3 • AUTO RFL • (07-12-72) 07/25/72

```
              SUBROUTINE BORE                                                   BORE
        C     ELEMENT - ROCK DISINTEGRATION                                     BORE
        C     GENERAL PROCESS - BORING MACHINE                                  BORE
        C     ACTIVITY - BORE                                                   BORE
        C     TECHNIOUE - ROLLING DISC CUTTERS                                  BORE
000002        COMMON /BORING/ CL(3),CPC,OTA,DTC,DTCD,DTD,DTM,KK,PBM,R(100),RC   BORING
             A, RPM,TR,XCPC, MASSEM,MBM,MBORF,MCD,MDISAS,LNCHNG,LNCUTR,NCUT(20) BORING
             B, WEAR(100),EBORFO,ETRANS                                         BORING
000002        COMMON /ALL   / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG                  ALL
             1, AT,D,E,SK,T,DT,X,PR,XMAX,TMAX,DX,DV,TPRINT,DTPRNT,IMOVE,JMETH   ALL
             2, TSHFT,REPORT,OPPCT,TO,XO,XDISCH,ICHNG,XCHNG,TCHNG               ALL
000002        EQUIVALENCE (JMOVF,IMOVE),(IMETH,JMETH)                           ALL
000002        COMMON/MONEY/ JMMHM,DJM,DJMMH,DJMRD,DJMBMM,DMAINT,DJMBM,DJMGS     ALL
             1, PMGS,JMCV,DJMFC,ROPLAN,HPLANT,GSPLAN                            ALL
             2, ECPLAN,RDTIME,HIIME(2),GSTIME,ECTIME                            ALL
000002        COMMON/PERFRM/ ROUTIM,RDDTIM,UMHTIM,DMHTIM,GSUTIM,GSDTIM,ECUTIM   ALL
             I, ECDTIM,GDAY,GADV,GEND,GBEG                                      ALL
000002        COMMON/LABOR/ RDMFN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2)    ALL
000002        REAL JMMHM,LD,LDB,LBIT,LBURN,LSTEEL,JMCV                          ALL
000002        DIMENSION G(8)                                                    ALL
000002        EQUIVALENCE (G,XT),(XE,XOE),(PR,PC)                               ALL
000002        DATA (RDUTIME=0.),(RDDTIME=0.)                                    BORE
000002        DATA NEEOIN,INIT,IESET/3*0/                                       BORE
        C     OPTION 2 - DIAMETER WITHIN 6-20 FT. AND STRENGTH WITHIN 5-30E3PSI BORE
000002      1 IF(D .GT. 20.1 .OR. D .LT. 6.0) GO TO 10                          BORE
000013        IF (STR .GT. 30.I .OR. STR .LT. 5.0) GO TO 10                     BORE
000023        INIT=I                                                            BORE
000024        IF(PBM .EO. 0.) PBM=40.*EXP(.19*D)                                BORE
000032        IF(PR .EO. 0.) PR=.02                                             BORE
000034        IF(E .NE. 0.) GO TO 5                                             BORE
000035        IESET=I                                                           BORE
000036      5 IF(NEEOIN .EO. 0) GO TO 999                                       BORE
000037        NEEOIN=0                                                          BORE
000040        GO TO 25                                                          BORE
000040     10 PRINT 20                                                          BORE
000044     20 FORMAT (  87H BORING MACHINE PARAMETERS MUST BE SPECIFIED FOR THIS BORE
             I TUNNEL DIAMETER OR ROCK STRENGTH         )                       BORE
000044        STOP                                                              BORE
        C                                                                       BORE
000046        ENTRY BORER                                                       BORE
000053     25 IF(INIT .EO. 1) GO TO 28                                          BORE
000055        NEEDIN=1                                                          BORE
000056        GO TO I                                                           BORE
000057     28 IF(IESET .EO. 0) GO TO 29                                         BORE
000060        E=I.8*EXP(.084*STR)                                               BORE
000066     29 CONTINUE                                                          BORE
        C                                                                       BORE
        C      COMPUTING LABOR TIME USED FOR THIS ACTIVITY                      BORE
        C                                                                       BORE
000066        RDTIME=RDTIME+DT                                                  BORE
000070        IF (MBORE.NE.0) GOTO 40                                           BORE
000071     30 DJMRD=DJMRD + PBM * .746 * PR * DT                                BORE
000076        DX=PBM*DT/AT/E*550.*3600./144000.                                 BORE
000102        DV=DX*AT                                                          BORE
        C                                                                       BORE
```

```
        C       CONPUTING UP TIME FOR ROCK OISINTEGRATION
        C
000103          RDUTIM=RDUTIM+DT
        C
        C       COMPUTING PLANT ANO EQUIPMENT COSTS FOR BORING
        C
000105       35 RDPLAN=RDPLAN+DX*EBOREQ+DX*ETRANS
000111          RETURN
        C
000112       40 DX=0.
000113          DV=0.
000114          IF(MBORE .GE. 3) GO TO 35
000117          RDDTIM=RDDTIM+DT
000121      999 CONTINUE
000121          RETURN
000122          END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
IMOVE
JMETH
XT
XOE
PC
JMOVE
IMETH
XE
```

H. SUBROUTINE CUTTER

GOLETA FORTRAN 1.3 * AUTO RFL * (07-12-72) 07/25/72

```
                  SUBROUTINE CUTTER
          C       ELEMENT - ROCK DISINTEGRATION
          C       GENERAL PROCESS - BORING MACHINE
          C       ACTIVITY - CUTTER CHANGE
          C       TECHNIQUE - ROLLING DISC CUTTERS
000002            COMMON /BORING/ CL(3),CPC,DTA,DTC,DTCD,DTD,DTM,KK,PBM,R(100),RC
                 A, RPM,TR,XCPC, MASSEM,MBM,MBORE,MCD,MDISAS,LNCHNG,LNCUTR,NCUT(20)
                 B,  WEAR(100),EBOREQ,ETRANS
000002            COMMON /ALL    / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG
                 1,  AT,D,E,SK,T,DT,X,PR,XMAX,TMAX,DX,DV,TPRINT,DTPRNT,IMOVE,JMETH
                 2,  TSHFT,REPORT,OPPCT,TO,XO,XDISCH,ICHNG,XCHNG,TCHNG
000002            EQUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)
000002            COMMON/MONEY/ JMMHM,DJM,DJMMH,DJMRD,DJMBMM,DMAINT,DJMBM,DJMGS
                 1,  PMGS,JMCV,OJMFC,RDPLAN,HPLANT,GSPLAN
                 2,  ECPLAN,ROTIME,HTIME(2),GSTIME,ECTIME
000002            COMMON/PERFRM/ RDUTIM,RDOTIM,UMHTIM,DMHTIM,GSUTIM,GSDTIM,ECUTIM
                 1,  ECDTIM,GDAY,GADV,GENO,GREG
000002            COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2)
000002            REAL JMMHM,LD,LOB,LBIT,LBURN,LSTEEL,JMCV
000002            DIMENSION G(8)
000002            EQUIVALENCE (G,XT),(XE,XDE),(PR,PC)
000002            DATA (TENPI=31.415926235898)
000002            IF (RPM .GT.0.0) GOTO 11
000005            RPM = 5.0
000006            CL(1)=1000000.
000007            CL(2)=400000.
000010            CL(3)=100000.
000012            RC = .75
000013            KK=D/.48 +.9
000017            R(1)=2.88
000021            DO 10 K=2,KK
000022            R(K)=R(K-1)+2.88
000025         10 CONTINUE
000027            CPC = 80.
000030            XCPC=3.38
000032            TR = .5
000033         11 DO 15 K = 1,KK
000035         15 WEAR(K) = 0.0
000040            TIME = 0.0
000041            LNCUTR=0
000042            RETURN
          C
000042            ENTRY CUTCHG
          C
000047            IF (LNCUTR .NE. 0) GO TO 30
000050             LNCHNG=0
000051            MK = 0
000052            IF (MBORE.NE.0) RETURN
000053            DO 21 K=1,KK
          C       CALCULATE CUTTER WEAR
000055            WEAR(K)=WEAR(K)+TENPI*RPM*DT*R(K)/CL(IA)
000064            IF (WEAR(K).GE.1.) LNCUTR=1
000071         21 CONTINUE
000074            IF (LNCUTR.NE.1) RETURN
000076            DO 22 K=1,KK
```

```
000100          IF (WEAR(K) .LT. PC) GO TO 22
000103          WEAR(K) = 0.
000104          LNCUTR=1
000105          LNCHNG = LNCHNG + 1
000107          MK= MK+1
000110          NCUT(MK)=K
000111       22 CONTINUE
000114          IF (LNCUTR .EQ.0) GO TO 40
000115          TTIME = LNCHNG * TR
000117          DJMRD=DJMRD+LNCHNG*(1.0+XCPC)*CPC
000124          RETURN
000125       30 TIME = TIME + DT
000127          IF (TIME .GE. TTIME) GOTO 35
000131          LNCUTR=2
000132          RETURN
           C    CUTTER CHANGE COMPLETED
000133       35 TIME = 0.0
000134          LNCUTR = 0
000135       40 RETURN
000136          END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
IMOVE
JMETH
XT
XOE,
PC
JMOVE
IMETH
XE
PR
```

I. SUBROUTINE REPAIR

GOLETA FORTRAN 1.3 • AUTO RFL • (07-12-72)   07/25/72

```
                SUBROUTINE REPAIR                                               REPAIR     2
          C     GENERAL PROCESS - BORING MACHINE                                REPAIR     3
          C     ACTIVITY - GENERAL MAINTENANCE AND REPAIR                       REPAIR     4
000002          COMMON /BORING/ CL(3),CPC,DTA,DTC,DTCD,DTD,DTM,KK,PBM,R(100),RC BORING     2
               A, RPM,TR,XCPC, MASSEM,MBM,MBORE,MCD,MDISAS,LNCHNG,LNCUTR,NCUT(20) BORING  3
               B,  WEAR(100),EBOREQ,ETRANS                                      BORING     4
000002          COMMON /ALL    / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG               ALL        2
               1,  AT,D,E,SK,T,DT,X,PR,XMAX,TMAX,DX,DV,TPRINT,DTPRNT,IMOVE,JMETH ALL       3
               2,  TSHFT,REPORT,OPPCT,TD,XO,XOISCH,ICHNG,XCHNG,TCHNG            ALL        4
000002          EQUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)                         ALL        5
000002          COMMON/MONEY/ JMMHM,DJM,DJMMH,DJMRD,DJMBMM,DMAINT,DJMBM,DJMGS   ALL        6
               1,  PMGS,JMCV,DJMEC,RDPLAN,HPLANT,GSPLAN                         ALL        7
               2,  ECPLAN,RDTIME,HTIME(2),GSTIME,ECTIME                         ALL        8
000002          COMMON/PERFRM/ RDUTIM,RDDTIM,UMHTIM,DMHTIM,GSUTIM,GSDTIM,ECUTIM ALL        9
               1,  ECDTIM,GDAY,GADV,GEND,GREG                                   ALL       10
000002          COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2)  ALL       11
000002          REAL JMMHM,LD,LDB,LBIT,LBURN,LSTEEL,JMCV                        ALL       12
000002          DIMENSION G(8)                                                  ALL       13
000002          EQUIVALENCE (G,XT),(XE,XDE),(PR,PC)                             ALL       14
000002          IF (DTC .GT. 0.0) GO TO 5                                       REPAIR     7
000005          DTC = 7.                                                        REPAIR     8
000006          DTM = 1.                                                        REPAIR     9
000007          DJMBMM=0.                                                       REPAIR    10
000010        5 TM=0.                                                           REPAIR    11
000011          TIME=DTC                                                        REPAIR    12
000013          MBM=0                                                           REPAIR    13
000014          RETURN                                                          REPAIR    14
          C                                                                     REPAIR    15
000014          ENTRY MAINT                                                     REPAIR    16
          C     IS MAINTENANCE IN PROGRESS                                      REPAIR    17
000021       10 IF (MBM.NE.0) GOTO 20                                           REPAIR    18
000022          TIME=TIME-DT                                                    REPAIR    19
          C     IS MAINTENANCE REQUIRED                                         REPAIR    20
000024          IF (TIME.GT.0.) RETURN                                          REPAIR    21
000026          MBM=1                                                           REPAIR    22
000027          TM=0.                                                           REPAIR    23
000030          TIME=DTC                                                        REPAIR    24
000032          DJMBM=DJMBM+DJMBMM                                              REPAIR    25
000034           RETURN                                                         REPAIR    26
          C     IF IN PROGRESS, UPDATE PROGRESS                                 REPAIR    27
000034       20 TM = TM + DT                                                    REPAIR    28
000036          IF (TM.LT.DTM) RETURN                                           REPAIR    29
000041          MBM=0                                                           REPAIR    30
000042          TIME=DTC                                                        REPAIR    31
000044          RETURN                                                          REPAIR    32
000044          END                                                             REPAIR    33
•FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
IMOVE
JMETH
XT
XDE
PC
JMOVE
IMETH
XE
PR
```

J. SUBROUTINE CVLOAD

```
GOLETA FORTRAN 1.3 * AUTO REL * (07-12-72)                                               07/25/72

              SUBROUTINE CVLOAD                                             CVLOAD     2
          C                                                                 CVLOAD     3
          C   ELEMENT - MATERIALS HANDLING                                  CVLOAD     4
          C   GENERAL PROCESS - INTEGRATED CONT. EXCAVATOR-CONVEYOR LOADER  CVLOAD     5
          C   ACTIVITY - LOADING                                            CVLOAD     6
          C                                                                 CVLOAD     7
000002        COMMON /WHEELS/ AF,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,DE,DF,DTAS WHEELS  2
             1.  DTMA,DTU,FL,FC,FR,FT,HPA,HPEA,HPEV,HPFA,HPFV,HPV,LOCO,MC,ML  WHEELS  3
             2.  NCARS,NPOINT,NTD,NTM,NTMAX,XP,NTMILP,NTMLPP,NTRACK,SL       WHEELS     4
             3.  TCURVX(20),TCURVY(20),TMAINT,TWE,VD,VS,VE,VF,VMAX,WC,WL,XDS WHEELS     5
             4.  MAXLD,NUMLD,LQUE,QUC,WUC,STATUS(36),WHY(24),MLTYP,WMR,ECONEQ, WHEELS   6
             5   ECONSS,FLOOD,EMUCKC,ETRACK,ESWITC,EUNLDA,ERMAIN,ITBORE,     WHEELS     7
             6   ISW(25),NTINIT,TCCV,TMCV                                    WHEELS     8
000002        COMMON /OLDCOM/ IFILD,KSTOP(25),KUNLO,LSTOP,LVEHCL,NRYRY,NSWCH WHEELS     9
             1.  NTRDA,NVEHCL,NUMSWT,SWITCH(20),TFC(25),TOP(25),TSTAT(25,4)  WHEELS    10
             2.  UTIME(25),LOADR,MUKDT,XGS,IEXCA,MGS(5),MCV,MFLAGC,DUMMY(20) WHEELS    11
000002        COMMON /NEWCOM/ LIFILD,LKSTOP(25),LKUNLO,LLSTOP,LLVHCL,LNRYBY  WHEELS    12
             1.  LNSWCH,LNTRDA,LNVHCL,LNMSWT,FSWTCH(20),FTFC(25),FTOP(25)    WHEELS    13
             2.  FTSTAT(25,4),FUTIME(25),LLOADR,LMUKDT,FXGS,LIFXCA,LMGS(5)   WHEELS    14
             3.  LMCV,LMFLAC,FDUMMY(19)                                      WHEELS    15
000002        DIMENSION COMOLD(260),COMNEW(260),LTSTAT(25,4),TTSTAT(25,4)    WHEELS    16
000002        EQUIVALENCE (NVEHCL,NTRAIN,NTRUCK),(LVEHCL,LTRAIN,LTRUCK)      WHEELS    17
             1.  (COMOLD,IFILD),(COMNEW,LIFILD,IFILLD),(NTDA,LNTRDA)         WHEELS    18
             2.  (FTSTAT,LTSTAT),(TSTAT,ITSTAT)                              WHEELS    19
             3.  (LLVHCL,LLTRAN,LLTRUK),(LNVHCL,LNTRAN,LNTRUK)               WHEELS    20
000002        COMMON /ALL   / AT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG               ALL        2
             1.  AT,D,F,SK,T,DT,X,PR,XMAX,TMAX,DX,DV,TPRINT,DTPRNT,IMOVE,JMETH ALL      3
             2.  TSHFT,REPORT,DPRCT,TO,XO,XDISCH,ICHNG,XCHNG,TCHNG           ALL        4
000002        EQUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)                        ALL        5
000002        COMMON/MONEY/ JMMMM,DJM,DJMMH,DJMRD,DJMBMM,DMAINT,OJMBM,OJMGS  ALL        6
             1.  PMGS,JMCV,DJMEC,RDPLAN,HPLANT,GSPLAN                        ALL        7
             2.  ECPLAN,RDTIME,HTIME(2),GSTIME,ECTIME                        ALL        8
000002        COMMON/PERFRM/ RDUTIM,RDDTIM,UMHTIM,DMHTIM,GSUTIM,GSOTIM,ECUTIM ALL       9
             1.  ECDTIM,GDAY,GADV,GEND,GBEG                                  ALL       10
000002        COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2) ALL       11
000002        REAL JMMMM,LD,LDP,LBIT,LBURN,LSTEEL,JMCV                       ALL       12
000002        DIMENSION G(9)                                                 ALL       13
000002        EQUIVALENCE (G,XT),(XE,XDE),(PR,PC)                            ALL       14
000002        COMMON /CONVEY/    ACM,DTBS,DWM,FE,FL,HP,QC,SMIN,WBI           BELTS      2
             1.  WP,XLF,NSURGE,QE,QP,SM,DTCR,DTMR,AB,VBI,NEXON,NGEO,XE,LNSURG, UPDA7    1
             2   STIME,QQMR,DTMI,DTMO                                        UPDA7      2
000002        EQUIVALENCE (VB,VBI)                                           CVLOAD    11
000002        DATA INIT /0/                                                  CVLOAD    12
000002        DATA NFEDIN /0/                                                CVLOAD    13
000002        DATA DTLO /0./                                                 CVLOAD    14
000002        DATA DTEM /0./                                                 CVLOAD    15
000002        DATA QUF /0./                                                  CVLOAD    16
000002        DATA WUF /0./                                                  CVLOAD    17
          C                          INITIALIZE                              CVLOAD    18
000002     100 IF (AB * VB .EQ. 0.) GO TO 200                                CVLOAD    19
          C                          OPTION 1                                CVLOAD    20
000004        XWRK = AB * VB                                                 CVLOAD    21
000005        WMR = .03 * XWRK * CS / SK                                     CVLOAD    22
000011        QMR = 60. * XWRK                                               CVLOAD    23
000012        PRINT 101, QMR,WMR                                             CVLOAD    24
```

```
000022     101 FORMAT (10HO QMR,WMR= 2E14.6)                               CVLOAD
000022         GO TO 250                                                   CVLOAD
        C                           OPTION 2                               CVLOAD
000023     200 QMR = 2000. * WMR * SK / CS                                 CVLOAD
        C                           BOTH OPTIONS                           CVLOAD
000027     250 INIT = 1                                                    CVLOAD
000030         IF (NEEDIN .EQ. 0) GO TO 900                                CVLOAD
000031         NEEDIN = 0                                                  CVLOAD
000032         GO TO 370                                                   CVLOAD
        C                           NORMAL ENTRY                           CVLOAD
000032         ENTRY LOADCV                                                CVLOAD
000037     350 IF (INIT .EQ. 1) GO TO 370                                  CVLOAD
        C                           INITIALIZATION REQUIRED                CVLOAD
000041         NEEDIN = 1                                                  CVLOAD
000042         GO TO 100                                                   CVLOAD
        C                           PERFORM LOADING                        CVLOAD
000043     370 OTLD = OT                                                   CVLOAD
000045         OVLD = OV                                                   CVLOAD
        C                                                                  CVLOAD
        C       COMPUTING LABOR TIME USED FOR THIS ACTIVITY                CVLOAD
        C                                                                  CVLOAD
000046         HTIME(2)=HTIME(2)+OT                                        CVLOAD
000050         IF(MCV .NE. 0) GO TO 900                                    CVLOAD
000051         IF((MLTYP .NE. 2) .AND. (LVEHCL .EQ. 0)) GO TO 380          CVLOAD
        C                                                                  CVLOAD
        C       COMPUTING PLANT AND EQUIPMENT COSTS                        CVLOAD
        C                                                                  CVLOAD
000060         HPLANT=HPLANT+ECONEQ*DX+ECONSS*OX                           CVLOAD
000064     380 IF(LOADR .NE. 1) GO TO 390                                  CVLOAD
000066         OTLD = 2.* OT                                               CVLOAD
000070         DVLD = OV + QTEM                                            CVLOAD
000072     390 QDD = DVLD * SK / OTLD                                      CVLOAD
000075         WDD = DVLD * CS / (DTLD * SK * 2000.)                       CVLOAD
000100         IF (MLTYP .EQ. 2) GO TO 600                                 CVLOAD
        C                           UNITIZED MAIN LINE SYSTEM              CVLOAD
000102         IF (LLVHCL.LE.0) GOTO 700                                   CVLOAD
000104         LLOADR = 0                                                  CVLOAD
000105         IF (QTEM .EQ. 0.) GO TO 550                                 CVLOAD
        C                           ACCOUNT FOR MUCK FROM LAST CYCLE       CVLOAD
000106         QUF = QUF + QTEM                                            CVLOAD
000107         WUF = WUF + WTEM                                            CVLOAD
000111         QTEM = 0.                                                   CVLOAD
000112         WTEM = 0.                                                   CVLOAD
000112     550 IF (QDD .GT. QMR .OR. WDD .GT. WMR) GO TO 700               CVLOAD
000124         QUF = QUF + QDD * DTLD                                      CVLOAD
000126         WUF = WUF + WDD * DTLD                                      CVLOAD
000131         IF (QUC .GT. QUF .AND. WUC .GT. WUF) GO TO 900              CVLOAD
        C                           MAINLINE UNIT FULL, CAN BE RELEASED    CVLOAD
000142         I=LLVHCL                                                    CVLOAD
000143         LKSTOP(I)=5                                                 CVLOAD
000145         LTSTAT(I,1)=7                                               CVLOAD
000146         QTEM = QUF - QUC                                            CVLOAD
000150         WTEM = WUF - WUC                                            CVLOAD
000152         QUF = 0.                                                    CVLOAD
000153         WUF = 0.                                                    CVLOAD
```

```
000153          GO TO 900
          C                               CONTINUOUS MAINLINE SYSTEM
000154      600 IF (QDD .GT. QMR .OR. WDO .GT. WMR) GO TO 700
000166          FQL = QDD
000167          GO TO 900
          C                               CONVEYOR CAPACITY EXCEEDED - TURN OFF
          C                                 EXCAVATOR NEXT CYCLE TO AVG. EXCESS OUT
000167      700 LLOADR = 1
000170          QTEM = DVLD
000172          WTEM = WDD * DTLD
000174      900 CONTINUE
000174          RETURN
000175          END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
NTRAIN
NTRUCK
LTRAIN
LTRUCK
IFILO
LIFILD
IFILLD
LNTRDA
LLTRAN
LLTRUK
LNTRAN
LNTRUK
IMOVE
JMETH
XT
XDE
PC
VBI
NVEHCL
NTDA
LNVHCL
JMOVE
IMETH
XE
PR
```

K. SUBROUTINE CVMNT


```
                 SUBROUTINE CVMNT                                                  CVMNT      2
          C                                                                        CVMNT      3
          C         ELEMENT MATERIALS HANDLING                                     CVMNT      4
          C         GENERAL PROCESS INTEGRATED CONVEYER EXCAVATOR, CONVEYER LOADER CVMNT      5
          C         ACTIVITY MAINTENANCE                                           CVMNT      6
          C                                                                        CVMNT      7
000002           COMMON /ALL   / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG                  ALL        2
                1, AT,D,E,SK,T,DT,X,PR,XMAX,TMAX,DX,DV,TPRINT,DTPRNT,IMOVE,JMETH   ALL        3
                2, TSHFT,REPORT,OPPCT,TO,XO,XDISCH,ICHNG,XCHNG,TCHNG               ALL        4
000002           EQUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)                           ALL        5
000002           COMMON/MONEY/ JMMHM,DJM,DJMMH,DJMRD,DJMBMM,DMAINT,DJMBM,DJMGS     ALL        6
                1, PMGS,JMCV,DJMEC,ROPLAN,HPLANT,GSPLAN                            ALL        7
                2, ECPLAN,RDTIME,HTIME(2),GSTIME,ECTIME                            ALL        8
000002           COMMON/PERFRM/ ROUTIM,RDDTIM,UMHTIM,DMHTIM,GSUTIM,GSDTIM,ECUTIM   ALL        9
                1, ECDTIM,GDAY,GADV,GEND,GBEG                                      ALL       10
000002           COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2)    ALL       11
000002           REAL JMMHM,LD,LDB,LBIT,LBURN,LSTEEL,JMCV                          ALL       12
000002           DIMENSION G(8)                                                    ALL       13
000002           EQUIVALENCE (G,XT),(XE,XDF),(PR,PC)                               ALL       14
000002           COMMON /WHEELS/ AE,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,DE,DF,DTAS   WHEELS     2
                1, DTMA,DTU,FL,FC,FR,FT,HPA,HPEA,HPEV,HPFA,HPFV,HPV,LOCO,MC,ML     WHEELS     3
                2, NCARS,NPOINT,NTD,NTM,NTMAX,XP,NTMILP,NTMLPP,NTRACK,SL           WHEELS     4
                3, TCURVX(20),TCURVY(20),TMAINT,TWE,VO,VS,VE,VF,VMAX,WC,WL,XDS     WHEELS     5
                4, MAXLD,NUMLD,LQUE,QUC,WUC,STATUS(36),WHY(24),MLTYP,WMR,ECONEQ,   WHEELS     6
                5  ECONSS,ELOCO,EMUCKC,ETRACK,FSWITC,EUNLOA,ERMAIN,IIBORE,         WHEELS     7
                6  ISW(25),NTINIT,TCCV,TMCV                                        WHEELS     8
000002           COMMON /OLDCOM/ IFILD,KSTOP(25),KUNLO,LSTOP,LVEHCL,NBYBY,NSWCH     WHEELS     9
                1, NTRDA,NVEHCL,NUMSWT,SWITCH(20),TFC(25),TOP(25),TSTAT(25,4)      WHEELS    10
                2, UTIME(25),LOADR,MUKOT,XGS,IEXCA,MGS(5),MCV,MFLAGC,DUMMY(20)     WHEELS    11
000002           COMMON /NEWCOM/ LIFILO,LKSTOP(25),LKUNLO,LLSTOP,LLVHCL,LNBYBY     WHEELS    12
                1, LNSWCH,LNTRDA,LNVHCL,LNMSWT,FSWTCH(20),FTFC(25),FTOP(25)        WHEELS    13
                2, FTSTAT(25,4),FUTIME(25),LLOADR,LMUKOT,FXGS,LIEXCA,LMGS(5)       WHEELS    14
                3, LMCV,LMFLAC,FDUMMY(19)                                          WHEELS    15
000002           DIMENSION COMOLD(260),COMNEW(260),LTSTAT(25,4),ITSTAT(25,4)       WHEELS    16
000002           EQUIVALENCE (NVEHCL,NTRAIN,NTRUCK),(LVEHCL,LTRAIN,LTRUCK)         WHEELS    17
                1,  (COMOLD,IFILD),(COMNEW,LIFILD,IFILLD),(NTDA,LNTRDA)            WHEELS    18
                2,  (FTSTAT,LTSTAT),(TSTAT,ITSTAT)                                 WHEELS    19
                3,  (LLVHCL,LLTRAN,LLTRUK),(LNVHCL,LNTRAN,LNTRUK)                  WHEELS    20
000002           DATA LMCV,MCV/2*0/                                                CVMNT     10
000002           DATA TRET,TMNT /2*0./                                             CVMNT     11
000002           DATA INIT,NEFDIN /2*0/                                            CVMNT     12
          C                          EQUIVALENCE FOR SPECIFIC GENERAL PROCESS      CVMNT     13
000002            EQUIVALENCE (GOJM,JMCV)                                          CVMNT     14
000002            EQUIVALENCE (MMNT,MCV)                                           CVMNT     15
000002            EQUIVALENCE (GDTC,TCCV)                                          CVMNT     16
000002            EQUIVALENCE (GDTM,TMCV)                                          CVMNT     17
000002            EQUIVALENCE (LMMNT,LMCV)                                         CVMNT     18
000002            EQUIVALENCE (MFLAG,MFLAGC)                                       CVMNT     19
000002            EQUIVALENCE (DJMGP,DJMMH)                                        CVMNT     20
000002           EQUIVALENCE(LMFLAG,LMFLAC)                                        CVMNT     21
          C                                                                        CVMNT     22
          C                          INITIALIZATION                                CVMNT     23
          C                                                                        CVMNT     24
000002        10 MMNT=0                                                            CVMNT     25
000003           IF(GDTC .EQ. 0.) GDTC=7.                                          CVMNT     26
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```
000005         IF(GDJM .EQ. 0.) GDJM=0.
000007         IF(GDTM .EQ. 0.) GDTM=1.
000011         TRET=GDTC
000012         INIT = 1
000013          IF (NEEDIN .EQ. 0) GO TO 999
000014         NEEDIN = 0
000015         GO TO 200
           C
           C                                NORMAL ENTRY
000015         ENTRY CVRPR
000022         IF (INIT .EQ. 1) GO TO 200
000024         NEEDIN = 1
000025         GO TO 10
           C                                IS MAINTENANCE IN PROGRESS
000026     200 IF (MMNT.NE.0) GOTO 400
000027         IF(MFLAG .NE. 0) GO TO 999
           C                                IS MAINTENANCE REQUIRED
000030         TRET = TRET - DT
000032         IF (TRET .GT. 0.) GO TO 999
           C            DOES ANY OTHER SITUATION EXIST SUCH THAT MAINTENANCE SHOULD
           C                 NOT BE PERMITTED. IF SO, GO TO 999
           C
           C          ACCUMULATING DOWN TIME
000034         LMMNT=1
000035         LMFLAG=1
000036         GO TO 999
           C                                UPDATE PROGRESS OF MAINTENANCE
000036     400 TMNT = TMNT + DT
000040         OMHTIM=OMHTIM+DT
           C                                IS MAINTENANCE COMPLETED
000042         IF (TMNT .LT. GDTM) GO TO 999
000044         DJMGP = DJMGP + GDJM
000046         TRET = GDTC
000047         TMNT = 0.
000047         LMMNT=0
000050         LMFLAG=0
000051     999 RETURN
           C   NOTE -- CHECK TESTING OF MFLAG IN RELATED SUBROUTINES
000052         END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
IMOVE
JMETH
XT
XOE
PC
NTRAIN
NTRUCK
LTRAIN
LTRUCK
IFILD
LIFILD
IFILLO
LNTROA
LLTRAN
LLTRUK
```

```
LNTRAN
LNTRUK
TCCV
TMCV
MFLAGC
DJMMH
LMFLAC
JMOVE
IMETH
XE
PR
NVEHCL
LVEHCL
NTDA
LLVHCL
LNVHCL
```

L. SUBROUTINE RAILHL

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GOLETA FORTRAN I.3 * AUTO RFL * (07-12-72)                                                    07/25/72

             SUBROUTINE RAILHL                                                         RAILHL
         C                                                                             RAILHL
         C        ELEMENT - MATERIALS HANDLING                                         RAILHL
         C        GENERAL PROCESS -CONVENTIONAL RAIL SYSTEM                            RAILHL
         C        ACTIVITY - LONG HAUL MUCK TRANSPORT (INCLUDES RETURN AND             RAILHL
         C                   TRAFFIC DELAYS)                                           RAILHL
         C        TECHNIQUE - TRACKS-DOUBLE OR SINGLE WITH CALIFORNIA SWITCHES         RAILHL
         C                    DRIVE - DIESEL OR ELECTRIC LOCOMOTIVE                    RAILHL
         C                                                                             RAILHL
         C   INSERT COMMON                                                             RAILHL
000002       COMMON /WHEELS/ AE,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,DE,DF,DTAS           WHEELS
            1,  DTMA,DTU,FL,FC,FR,FT,HPA,HPEA,HPEV,HPFA,HPFV,HPV,LOCO,MC,ML            WHEELS
            2,  NCARS,NPOINT,NTD,NTM,NTMAX,XP,NTMILP,NTMLPP,NTRACK,SL                  WHEELS
            3,  TCURVX(20),TCURV (20),TMAINT,TWF,VD,VS,VE,VF,VMAX,WC,WL,DS             WHEELS
            4,  MAXLD,NUMLD,LOLE,OUC,WUC,STATUS(36),WHY(24),MLTYP,WMR,ECONEQ,          WHEELS
            5   ECONSS,ELOCO,EMUCKC,ETRACK,ESWITC,EUNLOA,ERMAIN,IIBORE,                WHEELS
            6   ISW(25),NTINI,ICCV,THCV                                                WHEELS
000002       COMMON /OLDCOM/ IFILD,KSTOP(25),KUNLO,LSTOP,LVEHCL,NBYBY,NSWCH            WHEELS
            1,  NTRDA,NVEHCL,NUMSWT,SWITCH(20),TFC(25),TOP(25),TSTAT(25,4)             WHEELS
            2,  UTIME(25),LOADR,MUKOT,XGS,IEXCA,MGS(5),MCV,MFLAGC,DUMMY(20)            WHEELS
000002       COMMON /NEWCOM/ LIFILD,LKSTOP(25),LKUNLO,LLSTOP,LLVHCL,LNBYBY             WHEELS
            1,  LNSWCH,LNTRDA,LNVHCL,LNMSWT,FSWTCH(20),FTFC(25),FTOP(25)               WHEELS
            2,  FTSTAT(25,4),FUTIME(25),LLOADR,LMUKOT,FXGS,LIEXCA,LMGS(5)              WHEELS
            3,  LMCV,LMFLAC,FDUMMY(19)                                                 WHEELS
000002       DIMENSION COMOLD(260),COMNEW(260),LTSTAT(25,4),ITSTAT(25,4)               WHEELS
000002       EQUIVALENCE (NVEHCL,NTRAIN,NTRUCK),(LVEHCL,LTRAIN,LTRUCK)                 WHEELS
            1,  (COMOLD,IFILD),(COMNEW,LIFILD,IFILLO),(NTDA,LNTRDA)                    WHEELS
            2,  (FTSTAT,LTSTAT),(TSTAT,ITSTAT)                                         WHEELS
            3,  (LLVHCL,LLTRAN,LLTRUK),(LNVHCL,LNTRAN,LNTRUK)                          WHEELS
000002       COMMON /ALL    / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG                         ALL
            1,  AT,D,E,SK,T,DT,X,PR,XMAX,TMAX,DX,OV,TPRINT,DTPRNT,IMOVE,JMETH          ALL
            2,  TSHFT,REPORT,OPPCT,TO,XO,XDISCH,ICHNG,XCHNG,TCHNG                      ALL
000002       EQUIVALENCE (JMOVE,IMOVE),(IMFIH,JMETH)                                   ALL
000002       COMMON/MONEY/ JMMHM,OJM,DJMMH,OJMRO,OJMBMM,OMAINT,OJMBM,OJMGS             ALL
            1,  PMGS,JMCV,DJMFC,RDPLAN,HPLANT,GSPLAN                                   ALL
            2,  ECPLAN,RDTIME,HTIME(2),GSTIME,ECTIME                                   ALL
000002       COMMON/PERFRM/ RDUTIM,RDOTIM,UMHTIM,OMHTIM,GSUTIM,GSOTIM,ECUTIM           ALL
            1,  ECOTIM,GDAY,GADV,GENO,GBEG                                             ALL
000002       COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2)            ALL
000002       REAL JMMHM,LD,LDR,LBIT,LBURN,LSTEEL,JMCV                                  ALL
000002       DIMENSION G(8)                                                            ALL
000002       EQUIVALENCE (G,XT),(XE,XOE),(PR,PC)                                       ALL
000002       DATA INITSW, IRETSW /2*0/                                                 RAILHL
000002       DATA IOPTN /1/                                                            RAILHL
000002       DIMENSION KTEMP(25),KTRAIN(25),ISTATE(25,4),STATE(25,4)                   RAILHL
            1,  JSTOP(25),TTFC(25),TTOP(25)                                            RAILHL
000002       DATA (KTEMP=25*0),(KTRAIN=25*0),(STATE =100*0.)                           RAILHL
            1,  (JSTOP=25*0),(TTFC=25*0.),(TTOP=25*0.),(V=0.)                          RAILHL
000002       EQUIVALENCE (STATE,ISTATE)                                                RAILHL
         C                                                                             RAILHL
         C                          PARAMETER INITIALIZATION                           RAILHL
         C                                                                             RAILHL
000002   100 INITSW = 1                                                                RAILHL
000003       MLFLS = SL/2.                                                             RAILHL
000003       IF(LOCO .EQ. 2) GO TO 110                                                 RAILHL
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000007          IF (FC .EQ.0.) FC = 0.0455
000011          IF (CP .EQ.0.) CP = 0.14
000013          GO TO 120
000014      110 FC=.746
000016          IF(CP .EQ. 0.) CP=.02
000020      120 IF(VE * VF .GT.0.) GO TO 200
       C                                OPTION 2
000024          IOPTN  = 2
000025          IF (FT .EQ. 0.) FT = 0.25
000027          IF (AMAX .EQ. 0.) AMAX = 9999.
000031          IF(EL .EQ. 0.) EL=0.8
000033          HPFAC = EL * 375.
000035          HPAFAC = HPFAC * HPA
000037          GE =(NCARS * WC) + WL
000042          GF = NCARS * (WC + 1.35 * CARCAP) + WL
000047          X1 = NCARS * MC + ML
000053          WE = GE / X1
000054          WF = GF / X1
000056          TTEA = FT * WL * 2000.
000060          AC = 6.65 * (CARCAP ** 0.39) * .005
       C                                COMPUTE  VE, RE, VF, RF
000066          C1 = 1.3 + (29. / WE)
000071          C2 = AC / (WF * MC)
000074          C4 = HPV * HPFAC
000076          REF1 = C1
000077          REF2 = C2
000101          A = .045 / C2
000102          B = C1 / C2
000103          C = -C4 / (C2 * GE)
000106          VE = CUBIC (A, B, C)
000111          IF (VE .GT. VMAX) VE = VMAX
000114          RE = GE*(C1 + (C2 * VE * VE) + (.045 * VE) )
000123          C1 = 1.3 + (29. / WF)
000126          C2 = AC / (WF * MC)
000131          RFF1 = C1
000132          RFF2 = C2
000134          A = .045 / C2
000135          B = C1 / C2
000136          C = -C4 / (C2 * GF)
000141          VF = CUBIC (A,B,C )
000144          IF (VF .GT. VMAX)  VF = VMAX
000147          RF = GF * (C1 + (C2 * VF * VF) + (.045 * VF) )
       C                                COMPUTE HPEV,HPFV
000156          HPEV = (RE*VF) / HPFAC
000161          HPFV = (RF*VF) / HPFAC
000163          GO TO 250
       C                                OPTION 1
000163      200 CONTINUE
000163          HPEAH = HPEA
000165          HPFAH = HPFA
       C                                BOTH OPTIONS
000166      250 DINCR=150.
000170          YWRK = VO
000171          IF (VS .GT. VD) YWRK = VS
000174          XWRK = 2640. * (VF * VF - YWRK * YWRK) / DF
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000200          IF (XWRK .LT. DINCR) OINCR = XWRK
000203          XWRK = 2640. * (VE * VE - VS * VS) / OE
000207          IF (XWRK .LT. OINCR) OINCR = XWRK
000212          OELMAX = DINCR / (5280. * VE)
000214          IF (NTRACK .EQ. 2) NUMSWT = 1
000217          CPFC = CP * FC
000221          SWHPE = HPEV * VS / VE
000224          SWHPF = HPFV * VS / VF
000226          PRINT 260, VF,VF,RE,RF,GE,GF,HPEV,HPFV
000252     260 FORMAT(23HORAIL PARAMETERS -   VE,7X,2HVF,7X,2HRE,7X,2HRF,7X,
         *            2HGE,7X,2HGF,6X,4HHPEV,5X,4HHPFV/17X,8(F8.3,1X) )
000252          QUC=CARCAP*NCARS*27.
000255          WUC=QUC*.05
000257          PRINT 261, QUC, WUC
000266     261 FORMAT (18HO TRAIN CAPACITY = F10.4, 17H CUBIC FEET AND
          1  F10.4, 5H TONS)
        C                           WAS CALL FOR INITIALIZATION ONLY
000266          IF (IRETSW) 270,999,270
000267     270 IRETSW = 0
000270          GO TO 350
        C
        C                           UPOATE TRAIN STATUS MATRIX
        C
000271          ENTRY RAILTR
        C                           HAS INITIALIZATION BEEN PERFORMED
000276          IF (INITSW) 350,320,350
000277     320 IRETSW = 1
000300          GO TO 100
000301     350 NITER=DT/DELMAX
000304          TFRAC=DT-NITER*OELMAX
        C
        C        COMPUTING LABOR TIME USEO FOR THIS ACTIVITY
        C
000307          HTIME(1)=HTIME(1)+OT
000310          IF(MFLAGC .NE. 0) GO TO 351
000311          IF(NUMLD .EQ. 0) GO TO 352
000312          IF(IIBORE .NE. 0) GO TO 351
        C
        C        COMPUTING UP TIME
        C
000313          UMHTIM=UMHTIM+OT
        C
        C        COMPUTING PLANT ANO EQUIPMENT COSTS
        C
000315     351 CONTINUE
000315          HPLANT=HPLANT+DT*(NTRAIN*ELOCO+NTRAIN*NCARS*EMUCKC)+
         10X*(ETRACK+NS*ESWITC+EUNLOA+ERMAIN)
000333          GO TO 353
        C
        C        COMPUTING DOWN TIME
        C
000334     352 OMHTIM=OMHTIM+OT
000336     353 CONTINUE
        C                           RETRIEVE /OLDWRK/ VARIABLES
000336          00 355 J=1,NTRAIN
```

```
000340          ISTATE(J,1) = ITSTAT(J,1)
000342          STATE(J,2) = TSTAT(J,2)
000345          STATE(J,3) = TSTAT(J,3)
000347          STATE(J,4) = TSTAT(J,4)
000351          JSTOP(J) = KSTOP(J)
000353          TTFC(J) = TFC(J)
000355          TTOP(J) = TOP(J)
000357      355 CONTINUE
000361          ISTOP = LSTOP
000362      360 LLTRAN = 0
000363          LRETRN  = 0
000364          DELTAT = DELMAX
000365          IF (NITER.NE.0) GOTO 362
000366          DELTAT=TFRAC
000370      362 CONTINUE
000370          LQUE=100
000371          DO 364 ITR=1,NTRAIN
000373          IF (ISTATE(ITR,1).NE.0) GOTO 364
000375          IF (JSTOP(ITR).GT.100) LQUE=LQUE+1
000401      364 CONTINUE
000404          IBRNCH = ISTOP + 1
000406          GO TO (500,400,450) IBRNCH
          C                               SYSTEM MUST BE SHUT DOWN
000414      400 DO 420 J=1,NTRAIN
000416          IF (JSTOP(J) .NE. 0) GO TO 420
000420          IWRK = ISTATE(J,1)
000421          IF ((IWRK-10) * (IWRK-11) .EQ. 0) GO TO 420
000426          JSTOP(J) = 4
000430          IF ((IWRK-6)*(IWRK-7) .EQ. 0) GO TO 420
000435          JWRK = (IWRK + 1) / 2
000437          IWRK = IWRK / 2
000441          IS = 7
000442          IF (IWRK .EQ. JWRK) IS = 6
000445          ISTATE(J,1) = IS
000447      420 CONTINUE
000452          GOTO 500
          C                               SYSTEM MUST BE BROUGHT UP
000452      450 DO 470 J=1,NTRAIN
000454          IF (JSTOP(J) .NE. 4) GO TO 470
000457          JSTOP(J) = 0
000460          JWRK = ISTATE(J,1)
000461          IF (JWRK .EQ. 0) ISTATE(J,1) = 2
000464          IF (JWRK .EQ. 1) ISTATE(J,1) = 3
000470      470 CONTINUE
000473      475 ISTOP = 0
          C                               APPLY DELTA-T TO ALL TRAINS
000474      500 DO 750 I = 1,NTRAIN
000476          DELTAC = 0.
000477          STATE(I,4) = STATE(I,4) + (DELTAT / 24.)
000502          ISTAT = ISTATE(I,1)
000504          TPOS = STATE(I,2)
000506          TSPO = STATE(I,3)
000507          IKTEMP = KTEMP(I)
000511          IJSTOP = JSTOP(I)
000512          IISW = ISW(I)
```

```
000514          SWPOS = 0
000515          IF (IISW .GT. 0) SWPOS = SWITCH(IISW)
000520          IBRNCH = ISTAT + 1
000522          GO TO (510,530,550,570,590,610,630,650,670,690,700,700) IBRNCH
           C                            TRAIN IS EMPTY, AND HAS STOPPED
000541      510 IF (IJSTOP.GT.100) GOTO 511
000545          GOTO (514,516,520,1000,1000,600) IJSTOP
           C                            TRAIN IS IN LOAD QUEUE
000556      511 CONTINUE
000556          GOTO 698
           C                            TRAIN IS BEING LOADED
000557      514 LLTRAN=I
000561          GOTO 698
           C                            TRAIN IN SWITCH, WITH ANOTHER STOPPED AHEAD
000561      516 IF(ISTATE(IKTEMP,1) .EQ. 0) GO TO 700
000563          TPOS = SWPOS - HLFLS
000565          ISTAT = 2
000566          IKTEMP = 0
000567          IJSTOP = 0
000570          GO TO 698
           C                            TRAIN IN SWITCH, WITH ANOTHER APPROACHING
000570      520 IF(STATE(IKTEMP,2) .GT. SWPOS-HLFLS) GO TO 700
000576          LRETRN = 1
000577          GO TO 636
000577      522 ISTAT = 2
000600          TPOS = SWPOS + HLFLS
000602          IKTEMP = 0
000603          IJSTOP = 0
000604          GO TO 698
           C                            TRAIN IN IST SWITCH, AWAITING DISCHARGE
000604      524 IF (IFILLD .EQ. 1) GO TO 700
000606          LRETRN = 5
000607          GOTO 662
           C                            TRAIN IS FULL AND STOPPED
000610      530 IF (IJSTOP.GT.5) GOTO 1000
000614          GOTO (1000,536,542,1000,524) IJSTOP
           C                            TRAIN IN SWITCH, ANOTHER STOPPED AHEAD
000624      536 IF (ISTATE(IKTEMP,I) .EQ. 1) GO TO 700
000627          LRETRN = 3
000630          GO TO 662
           C                            TRAIN IN SWITCH, ANOTHER APPROACHING
000630      542 IF(STATE(IKTEMP,2) .LT. SWPOS-HLFLS) GO TO 700
000635          LRETRN = 5
000636          GO TO 656
           C                            TRAIN IS ACCELERATING EMPTY
000637      550 IF (IOPTN - )) 584,553,584
000642      551 RE = GE * (REF1 + (TSPD*(REF2*TSPD+0.045)))
000650          AFA = TEA - RE
000652          IF (AFA .LT. 0.) AFA = 0.
000654          AE = 39.4 * AFA / GE
000657          IF (AMAX .LT. AE) AE = AMAX
000662      553 YI = AE * DELTAT
000664          TPOS = TPOS+DELTAT*((2640.*YI)+(5280.*TSPD))
000672          TSPD = TSPD + YI
000673          IF (IOPTN.EQ.2) HPEAH= (AE * GE/39.4 +RE) * (TSPD/HPFAC)
```

```
000703          IF (HPA .GT. 0. .AND. HPEAH .GT. HPA) HPEAH = HPA
000713          DELTAC = HPEAH
000714          IF (TSPD - VE) 558,554,554
000717      554 ISTAT = 4
000720          TSPD = VE
000722      558 DO 562 J=1,NUMSWT
000724          A = SWITCH(J) - HLFLS - TPOS
000730          IF (A .LT. 0.) GO TO 562
000731          B = 2640. * ((TSPD*TSPD)-(VS*VS)) / DE
000736          IF (A .GT. B) GO TO 562
000741          ISTAT = 6
000742          IISW = J
000743          GO TO 698
000744      562 CONTINUE
000747          IISW = 0
000750          GO TO 698
          C                           TRAIN IS ACCELERATING FULL
000750      570 IF (IOPTN - 1) 584,572,584
000753      571 RF = GF * (RFF1 + (TSPD * (RFF2*TSPD + 0.045)))
000761          AFA = TEA - RF
000763          IF (AFA .LT. 0.) AFA = 0.
000765          AF = 39.4 * AFA / GF
000770          IF (AMAX .LT. AF) AF = AMAX
000773      572 Y1 = AF * DELTAT
000775          TPOS = TPOS - DELTAT*((5280.*TSPD)+(2640.*Y1))
001002          TSPD = TSPD + Y1
001004          IF (IOPTN.EQ.2) HPFAH= (AF*GF/39.4 + RF) * (TSPD/HPFAC)
001014          IF (HPA .GT. 0. .AND. HPFAH .GT. HPA) HPFAH = HPA
001024          DELTAC = HPFAH
001025          IF (TSPD - VF) 578,574,574
001030      574 ISTAT = 5
001031          TSPD = VF
001033      578 IF(NTRACK .EQ. 2) GO TO 583
001035          DO 582 J=1,NUMSWT
001037          A = TPOS - (SWITCH(J) + HLFLS)
001043          IF (A .LT. 0.) GO TO 582
001044          B = 2640. * ((TSPD*TSPD)-(VS*VS)) / DF
001051          IF (A .GT. B) GO TO 582
001054          ISTAT = 7
001055          IISW = J
001056          GO TO 698
001057      582 CONTINUE
001062      583 IISW = 0
001063          B = 2640. * ((TSPD*TSPD)-(VD*VD)) / DF
001070          IF (TPOS .GT. B) GO TO 698
001073          ISTAT = 7
001074          IISW = 100
001075          GO TO 698
          C                           FIND TEA
001075      584 TEA = TTEA
001077          IF (HPA .EQ. 0.) GO TO 585
001100          Y1 = TEA
001101          IF (TSPD .NE. 0.) Y1 = HPAFAC/TSPD
001103          GO TO 589
001104      585 IF (TSPD .GT. TCURVX(1)) GO TO 586
```

```
001110          Y1 = TCURVY(1)                                                RAILHL
001111          GO TO 589                                                     RAILHL
001111      586 DO 588 K = 2,NPOINT                                           RAILHL
001113          XWRK = TCURVX(K)                                              RAILHL
001115          IF(XWRK .LT. TSPD) GO TO 588                                  RAILHL
001117          YWRK = TCURVY(K)                                              RAILHL
001121          Y1 = YWRK-((XWRK-TSPD)*(YWRK-TCURVY(K-1))/(XWRK-TCURVX(K-1)))  RAILHL
001131          GO TO 589                                                     RAILHL
001131      588 CONTINUE                                                      RAILHL
001134          Y1 = TCURVY(NPOINT)                                           RAILHL
001135      589 CONTINUE                                                      RAILHL
001135          IF (Y1 .LT. TEA) TEA = Y1                                     RAILHL
001140          IF (ISTAT - 2) 571,551,571                                    RAILHL
          C                         TRAIN EMPTY, GOING AT FULL SPEED          RAILHL
001143      590 TPOS = TPOS + (5280. * VE * DELTAT)                           RAILHL
001147          DELTAC = HPEV                                                 RAILHL
001150          GOTO 554                                                      RAILHL
          C                         TRAIN IN SWITCH, WAITING TO ENTER LOAD AREA RAILHL
001150      600 IF (NUMLO.GE.MAXLD) GOTO 700                                  RAILHL
001153          LRETRN=1                                                      RAILHL
001154          GOTO 643                                                      RAILHL
          C                         TRAIN FULL, GOING AT FULL SPEED           RAILHL
001154      610 TPOS = TPOS - (5280. * VF * DELTAT)                           RAILHL
001160          DELTAC = HPFV                                                 RAILHL
001161          GOTO 574                                                      RAILHL
          C                         TRAIN IS DECELERATING EMPTY               RAILHL
001161      630 Y1 = DE * DELTAT                                              RAILHL
001163          TPOS = TPOS + DELTAT * ((5280.*TSPD)-(2640.*Y1))              RAILHL
001170          TSPD = TSPD - Y1                                              RAILHL
001172          IF (TSPD .GT. 0.) GO TO 634                                   RAILHL
001174          ISTAT = 0                                                     RAILHL
001174          TPOS=SWITCH(IISW)                                             RAILHL
001176          TSPD = 0.                                                     RAILHL
001177          IF (IJSTOP.NE.0) GOTO 698                                     RAILHL
001200          LRETRN=1                                                      RAILHL
001201          GOTO 6636                                                     RAILHL
001201      634 IF (ISTOP .EQ. 1) GO TO 698                                   RAILHL
001203          IF (IISW .EQ. 0) GO TO 698                                    RAILHL
001204          IF (TSPD .GT. VS) GO TO 648                                   RAILHL
001210      636 IF (IISW-(NUMSWT-1)) 638, 6638,6636                           RAILHL
001213     6636 LQUE=LQUE+1                                                   RAILHL
001215          NUMLD=LQUE-99                                                 RAILHL
001217          IF (NUMLD.LE.MAXLD) GOTO 627                                  RAILHL
001221          PRINT 6637                                                    RAILHL
001225     6637 FORMAT (30H0  TOO MANY TRAINS AT THE FACE  )                  RAILHL
001225          CALL  EXIT                                                    RAILHL
001226      627 CONTINUE                                                      RAILHL
001226          IJSTOP=LQUE                                                   RAILHL
001230          GOTO 648                                                      RAILHL
001230      637 IJSTOP=6                                                      RAILHL
001231          IKTEMP=0                                                      RAILHL
001232          GOTO 648                                                      RAILHL
001233     6638 IF (NUMLO-MAXLO) 643,637,637                                  RAILHL
001236      638 X1 = SWITCH(IISW + 1)                                         RAILHL
001240          RMAX = X1 + HLFLS                                             RAILHL
```

```
001242          RMIN = XI - HLFLS
001243          DO 642 K=1,NTRAIN
001245          IF (I .EQ. K) GO TO 642
001246          XI = STATE(K,2)
001250          IF (XI .GT. RMAX) GO TO 642
001253          IF (XI .LT. RMIN) GO TO 642
001255          IWRK = ISTATE(K,I)
001257          IF (IWRK * (IWRK-6) .NE. 0) GO TO 639
001262          IKTEMP = K
001263          IJSTOP = 2
001264          GO TO 648
001264      639 IF (IWRK .NE. 8) GO TO 640
001266          IKTEMP = 0
001267          IJSTOP = 0
001270          GO TO 642
001270      640 IF(IWRK .NE. 9) GO TO 641
001272          IKTEMP = K
001274          IJSTOP = 3
001275          GO TO 648
001275      641 IF ((IWRK-I) * (IWRK-7)  .NE. 0) GO TO 642
001302          IKTEMP = 0
001303          IJSTOP = 0
001304      642 CONTINUE
001307      643 CONTINUE
001307          RMAX = SWITCH(IISW + I) - HLFLS
001312          RMIN = SWITCH(IISW) + HLFLS
001314          DO 646 K=1,NTRAIN
001316          IF (I .EQ. K) GO TO 646
001317          XI = STATE(K,2)
001321          IF (XI .GT. RMAX) GO TO 646
001324          IF (XI .LT. RMIN) GO TO 646
001326          IWRK = ISTATE(K,I)
001330          IF((IWRK-I)*(IWRK-3)*(IWRK-5)*(IWRK-7) .NE. 0) GO TO 644
001344          IKTEMP = K
001345          IJSTOP = 3
001346          GO TO 648
001346      644 IF (IWRK * (IWRK -6) .NE. 0) GO TO 646
001351          IKTEMP = K
001353          IJSTOP = 2
001354          GO TO 648
001354      646 CONTINUE
001357          IF (LRETRN .EQ. I) GO TO 522
001361          ISTAT = 8
001362          TSPD = VS
001363          IKTEMP = 0
001364          IJSTOP = 0
001365          GO TO 698
001365      648 IF (LRETRN .EQ. 1) GO TO 649
001367          ISTAT = 6
001370          GO TO 698
001371      649 ISTAT = 0
001372          GO TO 698
          C                         TRAIN IS DECELERATING FULL
001373      650 IF(JSTOP(I) .NE. 5) GO TO 652
001376          LRETRN=5
```

```
001377            GO TO 656
001377       652  Y1=DF*DELTAT
001401            TPOS = TPOS + DELTAT * ((2640.*Y1)-(5280.*TSPD))
001407            TSPD = TSPD - Y1
001410            IF (ISTOP .EQ. 1) GO TO 698
001412            IF(IISW .EQ. 100) GO TO 653
001414            IF (TSPD .GT. 0.)GO TO 651
001416            ISTAT = 1
001417            TSPD = 0
001417            GO TO 698
001420       651  IF (IISW .EQ. 0) GO TO 698
001421            IF(TSPD .GT. VS) GO TO 666
001425            GO TO 656
001425       653  IF(TSPD .LE. 0.) TPOS=0.
001430            IF(TPOS .GT. 0.) GO TO 666
001433            ISTAT = 10
001434            TPOS = 0
001434            TSPD = VO
001436            NTDA = NTDA + 1
001437            IF (NTDA .GE. NTO) IFILLO = 1
001442            GO TO 698
001443       656  IF (IISW .NE. 1) GO TO 658
001445            IF(IFILLO .NE. 1) GO TO 658
001447            IJSTOP = 5
001450            IKTEMP = 0
001451            GO TO 666
001451       658  IF (IISW .LE. 1) GO TO 662
001454            X1 = SWITCH(IISW - 1)
001455            RMAX = X1 + HLFLS
001457            RMIN = X1 - HLFLS
001460            DO 660 K=1,NTRAIN
001462            IF (I .EQ. K) GO TO 660
001463            XI = STATF(K,2)
001465            IF (XI .GT. RMAX) GO TO 660
001470            IF (XI .LT. RMIN) GO TO 660
001472            IWRK = ISTATF(K,1)
001474            IF ((IWRK-1)*(IWRK-7) .NE. 0) GO TO 6584
001501            IKTEMP = K
001502            IJSTOP = 2
001503            GO TO 666
001504      6584  IF(IWRK .NE. 9) GO TO 6586
001506            IKTEMP = 0
001507            IJSTOP = 0
001510            GO TO 660
001510      6586  IF (IWRK .NE. 8) GO TO 6588
001512            IKTEMP = K
001514            IJSTOP = 3
001515            GO TO 666
001515      6588  IF ((IWRK-6)*IWRK .NE. 0) GO TO 660
001520            IKTEMP = 0
001521            IJSTOP = 0
001522       660  CONTINUE
001525       662  RMAX = SWITCH(IISW) - HLFLS
001530            RMIN=0.
001531            IF (IISW.NE.1) RMIN=SWITCH(IISW-1)+HLFLS
```

```
001535          DO 664 K=1,NTRAIN
001537          IF (I .EQ. K) GO TO 664
001540          Y1 = STATE(K,2)
001542          IF (Y1 .GT. RMAX) GO TO 664
001545          IF(Y1 .LT. RMIN) GO TO 664
001547          IWRK = ISTATE(K,1)
001551          IF (IWRK * (IWRK-2) * (IWRK-4) * (IWRK-6) .NE. 0) GO TO 663
001561          IKTEMP = K
001562          IJSTOP = 3
001563          GO TO 666
001563      663 IF ((IWRK-1) * (IWRK-7) .NE. 0) GO TO 664
001570          IKTEMP = K
001572          IJSTOP = 2
001573          GO TO 666
001573      664 CONTINUE
001576          IF ((LRETRN-3) * (LRETRN-5) .EQ. 0) GO TO 6662
001603          ISTAT = 9
001604          TSPD = VS
001606          IKTEMP = 0
001607          IJSTOP = 0
001610          GO TO 698
001610      666 IF((LRETRN-4)*(LRETRN-5) .EQ. 0) GO TO 6666
001615          ISTAT = 7
001616          GO TO 698
001617     6662 ISTAT = 3
001620          TPOS = SWITCH(IISW) - HLFLS
001623          IKTEMP = 0
001624          IJSTOP = 0
001625          LRETRN=0
001626          GO TO 698
001626     6666 ISTAT = 1
001627          GO TO 698
        C                                   TRAIN EMPTY, TRAVELING IN SWITCH AT VS
001630      670 TPOS = TPOS + (5280. * VS * DELTAT)
001634          TSPD = VS
001634          DELTAC = SWHPE
001636          IF (TPOS - SWPOS - HLFLS .LT. 0.)GO TO 698
001641          ISTAT = 2
001642          IISW = 0
001643          GO TO 698
        C                                   TRAIN FULL, TRAVELING IN SWITCH AT VS
001644      690 TPOS = TPOS - (5280. * VS * DELTAT)
001650          DELTAC = SWHPF
001651          IF (SWPOS - HLFLS - TPOS .LT. 0.) GO TO 698
001654          ISTAT = 3
001655          IISW = 0
001656      698 ISTATE(I,1) = ISTAT
001660          STATE(I,2) = TPOS
001662          STATE(I,3) = TSPD
001664          ISW(I) = IISW
001666          KTEMP(I) = IKTEMP
001670          JSTOP(I) = IJSTOP
001671          DELTAC = DELTAC * CPFC * DELTAT
001674          DJMMH = DJMMH + DELTAC
001675          TTFC(I) = TTFC(I) + DELTAC
```

```
001677      700 TTOP(I) = TTOP(I) + DELTAT
001702      750 CONTINUE
         C
         C                            IS ANOTHER ITERATION REQUIRED FOR THIS DT
         C
001704          NITER = NITER - 1
001706          IF (NITER.GE.0) GOTO 360
         C                            UPDATE /NEWWRK/
001707      900 DO 920 J= 1,NTRAIN
001711          LTSTAT(J,1) = ISTATE(J,1)
001713          FTSTAT(J,2) = STATE(J,2)
001716          FTSTAT(J,3) = STATE(J,3)
001720          FTSTAT(J,4) = STATE(J,4)
001722          LKSTOP(J) = JSTOP(J)
001724          FTFC(J) = TTFC(J)
001726          FTOP(J) = TTOP(J)
001730      920 CONTINUE
001732          LLSTOP = ISTOP
001733      999 RETURN
001734     1000 PRINT 1010
001740     1010 FORMAT (20H0IMPOSSIBLE PATHS        )
001740          CALL EXIT
001741          END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
NTRUCK
LTRAIN
LTRUCK
IFILD
LIFILD
LNTRDA
LLTRUK
LNTRAN
LNTRUK
IMOVE
JMETH
XT
XDE,
PC
NVEHCL
LVEHCL
LLVHCL
LNVHCL
JMOVE
IMETH
XE
PR
```

M. FUNCTION CUBIC

```
GOLETA FORTRAN 1.3 * AUTO RFL * (07-12-72)                                07/25/72

                FUNCTION CUBIC (A,B,C)
        C
        C           THIS FUNCTION FINDS THE FIRST REAL ROOT OF A CUBIC
        C               EQUATION OF FORM X**3 + AX**2 + BX + C = 0
        C               USING CARDAN#S SOLUTION
        C
000006          P = B - ( (A*A) / 3.)
000010          Q = (2. * (A/3)**3) - (A*B/3.) + C
000017          T = P/3.
000021          U = Q/2.
000023          QL = T*T*T + U*U
000026          T = SQRT(QL)
000030          U = -U
000032          EX = 1./3.
000033          BAS = U + T
000034          AL = (ABS(BAS)) ** EX
000041          IF (BAS .LT. 0.) AL = -AL
000046          BAS = U - T
000050          BL = (ABS(BAS)) ** EX
000054          IF (BAS .LT. 0.) BL = -BL
000057          CUBIC = AL + BL - (A/3.)
000063          RETURN
000063          END
```

N. SUBROUTINE ADDTRN(1)

GOLETA FORTRAN I.3 * AUTO RFL * (07-12-72) 07/25/72

```
                 SUBROUTINE ADDTRN (I)
        C
        C             ELEMENT - MATERIALS HANDLING
        C             GENERAL PROCESS - CONVENTIONAL RAIL SYSTEM
        C             ACTIVITY - TRAIN INSERTION INTO SYSTEM FROM DISCHARGE AREA
        C                           (SINGLE TRACK SYSTEMS)
        C
        C        INSERT COMMON
000003           COMMON /WHEELS/ AE,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,DE,DF,DTAS
                1,  DIMA,DTU,EL,FC,FR,FT,HPA,HPEA,HPEV,HPFA,HPFV,HPV,LOCO,MC,ML
                2,  NCARS,NPOINT,NTD,NTM,NTMAX,XP,NTMILP,NTMLPP,NTRACK,SL
                3,  TCURVX(20),TCURVY(20),TMAINT,TWF,VD,VS,VE,VF,VMAX,WC,WL,XDS
                4,  MAXLD,NUMLD,LQUE,GUC,WUC,STATUS(36),WHY(24),MLTYP,WMR,ECONEQ,
                5   ECONSS,ELOCD,EMUCKC,ETRACK,FSWITC,EUNLOA,ERMAIN,IIBORE,
                6   ISW(25),NTINIT,ICCV,TMCV
000003           COMMON /OLDCOM/ IFILD,KSTOP(25),KUNLD,LSTOP,LVEHCL,NBYBY,NSWCH
                1,  NTRDA,NVEHCL,NUMSWT,SWITCH(20),TFC(25),TOP(25),TSTAT(25,4)
                2,  UTIME(25),LDADR,MUKDT,XGS,IEXCA,MGS(5),MCV,MF AGC,DUMMY(20)
000003           COMMON /NEWCOM/ LIFILD,LKSTOP(25),LKUNLO,LLSTOP,LLVHCL,LNBYBY
                1,  LNSWCH,LNTRDA,LNVHCL,LNMSWT,FSWTCH(20),FTFC(25),FTOP(25)
                2,  FTSTAT(25,4),FUTIME(25),LLOADR,LMUKOT,FXGS,LIEXCA,LMGS(5)
                3,  LMCV,LMFLAG,FDUMMY(19)
000003           DIMENSION COMOLD(260),COMNEW(260),LTSTAT(25,4),ITSTAT(25,4)
000003           EQUIVALENCE (NVEHCL,NTRAIN,NTRUCK),(LVEHCL,LTRAIN,LTRUCK)
                1,  (COMOLD,IFILD),(COMNEW,LIFILD,IFILLD),(NTDA,LNTRDA)
                2,  (FTSTAT,LTSTAT),(TSTAT,ITSTAT)
                3,  (LLVHCL,LLTRAN,LLTRUK),(LNVHCL,LNTRAN,LNTRUK)
000003           COMMON /ALL    / XT,SIR,IA,RQD,CS,TAMB,FLOW,IFLAG
                1,  AT,D,F,SK,T,DT,X,PR,XMAX,TMAX,DX,DV,TPRINT,DTPRNT,IMOVE,JMETH
                2,  TSHFT,REPORT,OPPCT,TO,XD,XDISCH,ICHNG,XCHNG,TCHNG
000003           EQUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)
000003           COMMON/MONEY/ JMMHM,DJM,DJMMH,DJMRD,DJMBMM,DMAINT,DJMBM,DJMGS
                1,  PMGS,JMCV,DJMEC,RDPLAN,HPLANT,GSPLAN
                2,  ECPLAN,RDTIME,HTIME(2),GSTIME,ECTIME
000003           COMMON/PERFRM/ RDUTIM,RDDTIM,UMHTIM,DMHTIM,GSUTIM,GSDTIM,ECUTIM
                1,  ECDTIM,GDAY,GADV,GEND,GBEG
000003           COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2)
000003           REAL JMMHM,LD,LDB,LBIT,LBURN,LSTEEL,JMCV
000003           DIMENSION G(8)
000003           EQUIVALENCE (G,XT),(XE,XDE),(PR,PC)
000003           DATA LEND /0/
000003           DIMENSION IQUEUE (25)
000003           DATA IQUEUE /25*0/
000003           HLFLS = SL / 2.
000005           IF (I.LE.LNTRAN) GOTO 100
000007           PRINT 50, I,LNTRAN
000017        50 FORMAT (25H ***REQUEST TO ADD TRAIN ,I3,19H IGNORED. NTRAIN = ,I2)
000017           GO TO 900
000021       100 IF (LEND .LE. 0) GO TO 300
000023           IF (IQUEUE(1) - I) 600,300,600
        C                                 NO TRAIN PRECEDING TRAIN 1 IN LOADING AREA
000024       300 CONTINUE
        C                                 IS THERE A TRAIN IN SWITCH I
000026           IF (NUMSWT.GT.1) GOTO 310
000030           IF (NUMLD-MAXLD) 410,600,600
```

```
000033      310 CONTINUE
000033          RMAX= SWITCH(1) + HLFLS
000035          RMIN= SWITCH(1) - HLFLS
000037          DO 400 K=1,NTRAIN
000040          XWRK = TSTAT(K,2)
000042          IF (XWRK .GT. RMAX) GO TO 400
000045          IF (XWRK .LT. RMIN) GO TO 400
          C                                   TRAIN K IS IN SWITCH 1
000047          IWRK = ITSTAT(K,1)
000051          IF (IWRK * (IWRK-6) * (IWRK-9) .EQ. 0 ) GO TO 600
000055      400 CONTINUE
000060      410 CONTINUE
          C                                   IS THERE A TRAIN IN 1ST SEGMENT OF TRACK
000060          RMAX = SWITCH(1) - HLFLS
000062          DO 500 K=1,NTRAIN
000064          IF (TSTAT(K,2) .GT. RMAX) GO TO 500
000070          IWRK = ITSTAT(K,1)
000071          IF (IWRK * (IWRK-6) * (IWRK-1) * (IWRK-3) * (IWRK-5) * (IWRK-7)
               *                 .EQ. 0 )  GO TO 600
000107      500 CONTINUE
          C                                   NEW TRAIN MAY PROCEED
000112          LTSTAT(I,1) = 2
000114          FTSTAT(I,2) = 0.
000115          FTSTAT(I,3) = VD
000117          LKSTOP(I) = 0
000120          IF (IQUEUE(1) .NE. I) GO TO 900
000122          FTSTAT(I,3) = 0.
000123          LEND = LEND - 1
000124          DO 550 J=1,LEND
000126          IQUEUE(J) = IQUEUE(J+1)
000130      550 CONTINUE
000132          IQUEUE(LEND+1) = 0
000133          GO TO 900
          C                                   NEW TRAIN CAN*T PROCEED
000134      600 LTSTAT(I,1) = 10
000136          FUTIME(I) = 0.
000137          IF (LEND .LE.0) GO TO 670
000141          DO 650 J=1,LEND
000142          IF (IQUEUE(J) .EQ. I) GO TO 900
000144      650 CONTINUE
000146      670 LEND = LEND + 1
000150          IQUEUE(LEND) = I
000152      900 CONTINUE
000152          RETURN
000153          END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
NTRUCK
LTRAIN
LTRUCK
IFILD
LIFILD
IFILLD
LNTRDA
LLTRAN
LLTRUK
```

```
LNTRUK
IMOVE
JMETH
XT
XDE
PC
NVEHCL
LVEHCL
NTDA
LLVHCL
LNVHCL
JMOVE
IMETH
XE
PR
```

O. SUBROUTINE RAILDS

```
GOLETA FORTRAN 1.3 * AUTO RFL * (07-12-72)                                                07/25/72

                 SUBROUTINE RAILDS                                                RAILDS    2
           C                                                                      RAILDS    3
           C         ELEMENT - MATERIALS HANDLING                                 RAILDS    4
           C         GENERAL PROCESS - CONVENTIONAL RAIL SYSTEM                   RAILDS    5
           C         ACTIVITY - UNLOAD MUCK AT DISCHARGE POINT                    RAILDS    6
           C         TECHNIQUE - SEVERAL, DEPENDING ON NTD AND DTU                RAILDS    7
           C     INSERT COMMON                                                    RAILDS    8
000002           COMMON /WHEELS/ AF,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,DE,DF,DTAS  WHEELS    2
                1.  OTMA,DTU,EL,FC,FR,FT,HPA,HPEA,HPEV,HPFA,HPFV,HPV,LDCD,MC,ML   WHEELS    3
                2.  NCARS,NPOINT,NTD,NTM,NTMAX,XP,NTMILP,NTMLPP,NTRACK,SL         WHEELS    4
                3.  TCURVX(20),TCURVY(20),TMAINT,TWE,VD,VS,VE,VF,VMAX,WC,WL,XDS   WHEELS    5
                4.  MAXLD,NUMLD,LDUE,QUC,WUC,STATUS(36),WHY(24),MLTYP,WMR,ECONEQ, WHEELS    6
                5   ECONSS,ELOCD,EMUCKC,ETRACK,ESWITC,EUNLOA,ERMAIN,IIBDRE,       WHEELS    7
                6   ISW(25),NTINIT,TCCV,TMCV                                      WHEELS    8
000002           COMMON /OLDCOM/ IFILD,KSTOP(25),KUNLD,LSTOP,LVEHCL,NBYBY,NSWCH   WHEELS    9
                1.  NTRDA,NVEHCL,NUMSWT,SWITCH(20),TFC(25),TOP(25),TSTAT(25,4)    WHEELS   10
                2.  UTIME(25),LDADR,MUKOT,XGS,IFXCA,MGS(5),MCV,MFLAGC,DUMMY(20)   WHEELS   11
000002           COMMON /NEWCOM/ LIFILD,LKSTOP(25),LKUNLO,LLSTOP,LLVHCL,LNBYBY    WHEELS   12
                1.  LNSWCH,LNTRDA,LNVHCL,LNMSWT,FSWTCH(20),FTFC(25),FTOP(25)      WHEELS   13
                2.  FTSTAT(25,4),FUTIME(25),LLDADR,LMUKOT,FXGS,LIEXCA,LMGS(5)     WHEELS   14
                3.  LMCV,LMFLAC,FDUMMY(19)                                        WHEELS   15
000002           DIMENSION COMOLD(260),COMNEW(260),LTSTAT(25,4),ITSTAT(25,4)      WHEELS   16
000002           EQUIVALENCE (NVEHCL,NTRAIN,NTRUCK),(LVEHCL,LTRAIN,LTRUCK)        WHEELS   17
                1.  (COMOLD,IFILD),(COMNEW,LIFILD,IFILLO),(NTOA,LNTROA)           WHEELS   18
                2.  (FTSTAT,LTSTAT),(TSTAT,ITSTAT)                                WHEELS   19
                3.  (LLVHCL,LLTRAN,LLTRUK),(LNVHCL,LNTRAN,LNTRUK)                 WHEELS   20
000002           COMMON /ALL   / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG                 ALL       2
                1.  AT,D,E,SK,T,DT,X,PR,XMAX,TMAX,DX,DV,TPRINT,DTPRNT,IMOVE,JMETH ALL       3
                2.  TSHFT,REPORT,DPPCT,TO,XO,XDISCH,ICHNG,XCHNG,TCHNG             ALL       4
000002           EQUIVALENCE (JMOVF,IMOVE),(IMETH,JMETH)                          ALL       5
000002           COMMON/MONEY/ JMMHM,DJM,DJMMH,DJMRD,DJMBMM,DMAINT,DJMRM,OJMGS    ALL       6
                1.  PMGS,JMCV,DJMEC,RDPLAN,HPLANT,GSPLAN                          ALL       7
                2.  ECPLAN,RDTIME,HTIME(2),GSTIME,ECTIME                          ALL       8
000002           COMMON/PERFRM/ RDUTIM,RDDTIM,UMHTIM,DMHTIM,GSUTIM,GSOTIM,ECUTIM  ALL       9
                1.  ECOTIM,GOAY,GADV,GEND,GREG                                    ALL      10
000002           COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2)   ALL      11
000002           REAL JMMHM,LO,LDB,LBIT,LBURN,LSTEEL,JMCV                         ALL      12
000002           DIMENSION G(8)                                                   ALL      13
000002           EQUIVALENCE (G,XT),(XE,XDE),(PR,PC)                              ALL      14
000002           EQUIVALENCE (LNTRDA,NCOUNT)                                      RAILDS   11
000002           DATA INITOS /0/                                                  RAILDS   12
000002           ENTRY TRUKDS                                                     RAILDS   13
000007           IF (INITOS .EQ. 1)  GO TO 100                                    RAILDS   14
           C                               INITIALIZE                             RAILDS   15
000011           INITOS = 1                                                       RAILDS   16
000012           DO 50 I=1,25                                                     RAILDS   17
000014           UTIME(I) = DTU                                                   RAILDS   18
000016        50 CONTINUE                                                         RAILDS   19
000017       100 IF (KUNLD .EQ. 1) GO TO 800                                      RAILDS   20
           C                               UPDATE TIMES FOR TRAINS UNLOADING      RAILDS   21
000021           NCOUNT = 0                                                       RAILDS   22
000022           DO 500  I=1,NTRAIN                                               RAILDS   23
000023           IF (ITSTAT(I,1) .NE. 10) GO TO 500                               RAILDS   24
000026           FUTIME(I) = UTIME(I) - DT                                        RAILDS   25
000031           NCOUNT = NCOUNT + 1                                              RAILDS   26
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```
000032          IF (FUTIME(I) .GT. 0.) GO TO 500                                   RAILDS
000036          IF (NTRACK .EQ. 1) GO TO 300                                       RAILDS
000040          LTSTAT(I,1) = 2                                                    RAILDS
000041          GO TO 400                                                          RAILDS
000042      300 CALL ADDTRN(I)                                                     RAILDS
000044          IF (LTSTAT(I,I) - 10) 400,500,400                                  RAILDS
          C                        TRAIN HAS BEEN ADDED                            RAILDS
000047      400 NCOUNT = NCOUNT - 1                                                RAILDS
000051          FUTIME(I) = DTU                                                    RAILDS
000053      500 CONTINUE                                                           RAILDS
000056          IF (NCOUNT - NTD)  600,620,640                                     RAILDS
000060      600 LIFILD = 0                                                         RAILDS
000061          GO TO 800                                                          RAILDS
000062      620 LIFILD = 1                                                         RAILDS
000063          GO TO 800                                                          RAILDS
000064      640 PRINT 645 , NCOUNT                                                 RAILDS
000072      645 FORMAT (45HOTOO MANY TRAINS IN DISCHARGE AREA. NCOUNT = ,I5)       RAILDS
000072          CALL EXIT                                                          RAILDS
000073      800 RETURN                                                             RAILDS
000074          END                                                                RAILDS
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
NTRUCK
LTRAIN
LTRUCK
IFILD
IFILLD
LNTRDA
LLTRAN
LLTRUK
LNTRAN
LNTRUK
IMOVE
JMETH
XT
XDE
PC
NVEHCL
LVEHCL
NTDA
LLVHCL
LNVHCL
JMOVE
IMETH
XE
PR
```

P. SUBROUTINE RAILEX

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GOLETA FORTRAN 1.3 * AUTO RFL * (07-12-72)                                                    07/25/72

                SUBROUTINE RAILEX                                                    RAILEX      2
          C                                                                          RAILEX      3
          C         ELEMENT - MATERIALS HANOLING                                     RAILEX      4
          C         GENERAL PROCESS - CONVENTIONAL RAIL SYSTEM                       RAILEX      5
          C         ACTIVITY - SYSTEM EXTENSION                                      RAILEX      6
          C         TECHNIQUE - SINGLE TRACK PLACED AHEAD OF CALIF. SWITCH           RAILEX      7
          C                                                                          RAILEX      8
          C     INSERT COMMON                                                        RAILEX      9
000002          COMMON /WHEELS/ AF.AF.AMAX.AMAXL.AMINL.BSL.CAPCAP.CP.DF.DF.DTAS      WHFELS      2
               1.  OTMA.DTU.FL.FC.FR.FT.HPA.HPFA.HPEV.HPFA.HPFV.HPV.LOCO.MC.ML       WHFELS      3
               2.  NCARS.NPOINT.NTD.NTM.NTMAX.XP.NTMILP.NTMLPP.NTRACK.SL             WHFELS      4
               3.  TCURVX(20).TCURVY(20).TMAINT.TWE.VD.VS.VE.VF.VMAX.WC.WL.XDS       WHEELS      5
               4.  MAXLD.NUMLD.LOUE.QUC.WUC.STATUS(36).WHY(24).MLTYP.WMR.ECONEQ.     WHFELS      6
               5   ECONSS.ELOCD.FMUCKC.ETRACK.ESWITC.EUNLOA.EPMAIN.IIBORE.           WHEELS      7
               6   ISW(25).NTINIT.TCCV.TMCV                                          WHEELS      8
000002          COMMON /OLDCOM/ IFILO.KSTOP(25).KUNLO.LSTOP.LVEHCL.NBYBY.NSWCH       WHFELS      9
               1.  NTRDA.NVEHCL.NUMSWT.SWITCH(20).TFC(25).TOP(25).TSTAT(25.4)        WHEELS     10
               2.  UTIME(25).LOADR.MUKOT.XGS.IEXCA.MGS(5).MCV.MFLAGC.DUMMY(20)       WHFELS     11
000002          COMMON /NEWCOM/ LIFILO.LKSTOP(25).LKUNLO.LLSTOP.LLVHCL.LNBYBY        WHFELS     12
               1.  LNSWCH.LNTRDA.LNVHCL.LNMSWT.FSWTCH(20).FTFC(25).FTOP(25)          WHFELS     13
               2.  FTSTAT(25.4).FUTIMF(25).LLOADR.LMUKOT.FXGS.LIEXCA.LMGS(5)         WHEELS     14
               3.  LMCV.LMFLAC.FOUMMY()9)                                            WHEELS     15
000002          DIMENSION COMOLD(260).COMNEW(260).LTSTAT(25.4).ITSTAT(25.4)          WHEELS     16
000002          EQUIVALENCE (NVEHCL.NTRAIN.NTRUCK).(LVEHCL.LTRAIN.LTRUCK)            WHEELS     17
               1.  (COMOLO.IFILD).(COMNEW.LIFILO.IFILLD).(NTDA.LNTRDA)               WHEELS     18
               2.  (FTSTAT.LTSTAT).(TSTAT.ITSTAT)                                    WHEFLS     19
               3.  (LLVHCL.LLTRAN.LLTRUK).(LNVHCL.LNTRAN.LNTRUK)                     WHEELS     20
000002          COMMON /ALL   / XT.STR.IA.ROD.CS.TAMB.FLOW.IFLAG                     ALL         2
               1.  AT.D.F.SK.T.DT.X.PR.XMAX.TMAX.DX.DV.TPRINT.DTPRNT.IMOVE.JMETH     ALL         3
               2.  TSHFT.REPORT.OPPCT.TO.XO.XDISCH.ICHNG.XCHNG.TCHNG                 ALL         4
000002          EQUIVALENCE (JMOVE.IMOVE).(IMETH.JMETH)                              ALL         5
000002          COMMON/MONEY/ JMMHM.OJM.DJMMH.OJMRD.DJMBMM.DMAINT.DJMBM.DJMGS        ALL         6
               1.  PMGS.JMCV.OJMEC.RDPLAN.HPLANT.GSPLAN                              ALL         7
               2.  ECPLAN.ROTIME.HTIME(2).GSTIME.ECTIME                              ALL         8
000002          COMMON/PERFRM/ RDUTIM.RDOTIM.UMHTIM.DMHTIM.GSUTIM.GSOTIM.ECUTIM      ALL         9
               1.  ECDTIM.GDAY.GADV.GFNO.GREG                                        ALL        10
000002          COMMON/LABOR/ RDMFN()0.2).HMEN(10.2.2).GSMEN(10.2).ECMEN(10.2)       ALL        11
000002          REAL JMMHM.LD.LDB.LBIT.LBURN.LSTEEL.JMCV                             ALL        12
000002          DIMENSION G(8)                                                       ALL        13
000002          EQUIVALENCE (G.XT).(XE.XDE).(PR.PC)                                  ALL        14
000002          COMMON /CONVEY/    ACM.DTBS.DWM.EE.FL.HP.QC.SMIN.WBI                 BELTS       2
               1.  WP.XLF.NSURGE.QE.QP.SM.DTCB.DTMB.AB.VBI.NEXDN.NGEO.XE.LNSURG.     UPDA7       1
               2   STIME.QOMP.DTMI.DTMO                                              UPDA7       2
000002          DATA ALA /0./                                                        RAILEX     13
000002          DATA DTE /0./                                                        RAILEX     14
000002          DATA DTS /0./                                                        RAILEX     15
000002          DATA NEEDIN /0/                                                      RAILEX     16
000002          DATA S /0./                                                          RAILEX     17
000002          DATA INITEX /0/                                                      RAILEX     18
          C                                INITIALIZE                                RAILEX     19
000002          ENTRY TRUKEX                                                         RAILEX     20
000007      100 INITEX = 1                                                           RAILEX     21
000010          IF (XDE * XDS * BSL .GT.0.) GOTO 200                                 RAILEX     22
          C                                OPTION 2  (TEMPORARY VALUES)              RAILEX     23
000014          XDE = 5.                                                             RAILEX     24
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```
000015           XDS = 3.
000016           BSL = 5280.
           C                              BOTH OPTIONS HERE
000017       200 IF (NTRACK .EQ. 2) BSL = 0
000022           IF(AMINL .EQ. AMAXL) ALA=AMINL
000025           NDUMMY = 0
000026           NBYBY = 0
000027           PRINT 205, XDE,XDS,BSL
000040       205 FORMAT (30HORAIL EXTENSION - EXT. RATE =  F8.2,
                U  20H SWITCH MOVE RATE =  F8.2,
                2  29H DISTANCE BETWEEN SWITCHES =  F8.2)
           C                              WAS CALL FOR INITIALIZATION ONLY
000040           IF (NEEDIN)  900,900,210
000042       210 NEEDIN = 0
000043           GO TO 270
           C                              NORMAL ENTRY AFTER FIRST CALL
000044           ENTRY RAILXT
000051           ENTRY TRUKXT
           C                              HAS INITIALIZATION BEEN DONE
000056           IF (INITEX)  250,250,270
000060       250 NEEDIN = 1
000061           GO TO 100
000062       270 IF (NEXON .EQ. 1) GO TO 950
000064           NSWTCH = NSWCH
000066           IF (NSWTCH) 300,300,530
000067       300 IF (NGEO .EQ. 1) GO TO 350
           C                              CYCLIC  OPERATIONS GEOMETRY
000071           IF (DTE .EQ. 0.)  DTE = DX / XDE
000074           DTE = DTE - DT
000076           ALA = ALA + DX
000100           IF (DTE) 310,310,320
000101       310 LNBYBY = 0
000102           DTE = 0
000103           GO TO 330
000103       320 LNBYBY = 1
000104       330 GO TO 450
           C                              CONTINUOUS OPERATION
000105       350 ALA = ALA + (XDE * DT)
000110           S = S + DX - (XDF * DT)
000113           IF (S .GT. 0) GO TO 400
           C                              EXTENSION HAS CAUGHT EXCAVATOR
000115           XWRK = XDF * DT
000116           ALA = ALA - XWRK + DX
000121           S = S - DX + XWRK
000123           GO TO 450
000124       400 LNBYBY = 0
000125           IF (S .GE. SM) LNBYBY = 1
000131       420 CONTINUE
000131       450 IF (NSWTCH .GT. 0) GO TO 530
000134           IF (ALA .LT. AMAXL) GO TO 750
           C       IS SWITCH TO BE ADDED
000136           IF (BSL.EQ. 0) GO TO 510
000137           IF (NUMSWT .EQ. 1) GO TO 470
000141           XWRK = SWITCH(NUMSWT) - SWITCH(NUMSWT - 1)
000144           IF(XWRK-BSL-SL) 510,490,490
```

```
000147      470 IF(SWITCH(NUMSWT) -BSL-SL-XDISCH) 510,490,490
000155      490 NSWTCH = 1
000156          GO TO 530
000157      510 NSWTCH = 2
000160      530 CONTINUE
000160      550 IF (NSWTCH .EQ. 1)  GO TO 650
          C                              PUSH SWITCH FORWARD
000162          IF (DTS .NE. 0.) GO TO 600
000163          DTS = (AMAXL - AMINL) / XDS
000166          LNBYBY = 0
000167      600 DTS = DTS - DT
000171          IF (DTS .GT. 0.)  GO TO 750
000173          DTS = 0.
000173          NSWTCH = 0
000174          LNBYBY = 0
000175          ALA = AMINL
000176          IF(AMAXL .NE. AMINL) GO TO 620
000200          FSWTCH(NUMSWT) =SWITCH(NUMSWT)+DX
000203          DO 605 K=1,NTRAIN
000204          IF((KSTOP(K) .GE. 100) .OR. (KSTOP(K) .EQ. 1)) FTSTAT(K,2)=TSTAT(K
               1,2)+DX
000221      605 CONTINUE
000224          GO TO 750
000224      620 FSWTCH(NUMSWT)=SWITCH(NUMSWT)+AMAXL-AMINL
000231          DO 610 K=1,NTRAIN
000232          IF((KSTOP(K) .GE. 100) .OR. (KSTOP(K) .EQ. 1)) FTSTAT(K,2)=TSTAT(K
               1,2)+AMAXL-AMINL
000250      610 CONTINUE
000253          GO TO 750
          C                              ADD NEW SWITCH
000253      650 IF( DTS) 700,672,700
000254      672 DTS=DTAS
000256          NSWTCH=1
000257          LNBYBY = 0
000260      700 DTS = DTS - DT
000262          IF (DTS) 710,710,750
          C                              NEW SWITCH HAS BEEN ADDED
000263      710 DTS = 0.
000264          NSWTCH = 0
000265          LNBYBY = 0
000266          LNMSWT = NUMSWT + 1
000270          FSWTCH(LNMSWT)=SWITCH(NUMSWT)
000272          FSWTCH(NUMSWT)=SWITCH(NUMSWT)-SL
          C                              MUST NEW TRAIN BE ADDED
000275      750 XWRK=(X-XDISCH)/5280.
000300          YWRK = 0.
000301          IF (XWRK .LE. XP) GO TO 770
000303          X1 = XP/5280.
000305          YWRK = XWRK - X1
000306          XWRK = X1
000307      770 NTFIT=NTINIT+NTMILP*XWRK+NTMLPP*YWRK
000317          IF (NTFIT .GT. NTMAX) NTFIT = NTMAX
000322          IF (NTFIT - NTRAIN) 900,900,820
          C                              NEW TRAIN MUST BE ADDED
000325      820 IF (IFILLD .EQ. 1) GO TO 900
```

```
000327          LNTRAN = NTRAIN + 1
000331          L = LNTRAN
000332          FTSTAT(L,4) = 0.
000333          CALL ADDTRN(L)
000335          IF (LTSTAT(L,1) - 10) 900,870,900
000340      870 NTDA = NTDA + 1
000342          IF (NTDA .GE. NTD) IFILLD = 1
000345      900 LNSWCH = NSWTCH
000347      950 RETURN
000350          END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
NTRUCK
LTRAIN
LTRUCK
IFILD
LIFILD
LNTRDA
LLTRAN
LLTRUK
LNTRUK
IMOVE
JMETH
XT
PC
NVEHCL
LVEHCL
LLVHCL
LNVHCL
JMOVE
IMETH
XE
PR
```

Q. SUBROUTINE RAILMT

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GOLETA FORTRAN I.3 * AUTO RFL * (07-12-72)                                              07/25/72

                SUBROUTINE RAILMT                                              RAILMT      2
          C                                                                    RAILMT      3
          C          ELEMENT - MATERIALS HANDLING                              RAILMT      4
          C          GENERAL PROCESS - CONVENTIONAL RAIL SYSTEM                RAILMT      5
          C          ACTIVITY - GENERAL MAINTENANCE AND REPAIR OF LOCOMOTIVES * CAR RAILMT  6
          C                                                                    RAILMT      7
          C      INSERT COMMON                                                 RAILMT      8
000002          COMMON /WHEELS/ AF,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,DE,DF,DTAS WHEELS     2
               1,  DTMA,DTU,EL,FC,FR,FT,HPA,HPFA,HPEV,HPFA,HPFV,HPV,LOCO,MC,ML WHEELS     3
               2,  NCARS,NPOINT,NTO,NTM,NTMAX,XP,NTMILP,NTMLPP,NTRACK,SL       WHEELS      4
               3,  TCURVX(20),TCURVY(20),TMAINT,TWF,VD,VS,VE,VF,VMAX,WC,WL,XDS WHEELS      5
               4,  MAXLD,NUMLD,LQUE,OUC,WUC,STATUS(36),WHY(24),MLTYP,WMR,ECONEQ, WHEELS    6
               5   ECONSS,ELOCD,EMUCKC,ETRACK,FSWITC,EUNLOA,ERMAIN,IIBORE,     WHEELS      7
               6   ISW(25),NTINIT,TCCV,THCV                                    WHEELS      8
000002          COMMON /OLDCOM/ IFILD,KSTOP(25),KUNLO,LSTOP,LVFHCL,NBYRY,NSWCH WHEELS      9
               1,  NTRDA,NVEHCL,NUMSWT,SWITCH(20),TFC(25),TOP(25),TSTAT(25,4)  WHEELS     10
               2,  UTIME(25),LOADP,MUKOT,XGS,IEXCA,MGS(5),MCV,MFLAGC,OUMMY(20) WHEELS     11
000002          COMMON /NEWCOM/ LIFILO,LKSTOP(25),LKUNLO,LLSTOP,LLVHCL,LNBYRY  WHEELS     12
               1,  LNSWCH,LNTRDA,LNVHCL,LNMSWT,FSWTCH(20),FTFC(25),FTOP(25)    WHEELS     13
               2,  FTSTAT(25,4),FUTIME(25),LLOADR,LMUKOT,FXGS,LIEXCA,LMGS(5)   WHEELS     14
               3,  LMCV,LMFLAC,FDUMMY(19)                                      WHEELS     15
000002          DIMENSION COMOLD(260),COMNEW(260),LTSTAT(25,4),ITSTAT(25,4)    WHEELS     16
000002          EQUIVALENCE (NVFHCL,NTRAIN,NTRUCK),(LVEHCL,LTRAIN,LTRUCK)      WHEELS     17
               1,  (COMOLD,IFILD),(COMNEW,LIFILO,IFILLO),(NTOA,LNTROA)         WHEELS     18
               2,  (FTSTAT,LTSTAT),(TSTAT,ITSTAT)                              WHEELS     19
               3,  (LLVHCL,LLTRAN,LLTRUK),(LNVHCL,LNTRAN,LNTRUK)               WHEELS     20
000002          COMMON /ALL   / XT,STR,IA,RQO,CS,TAMB,FLOW,IFLAG               ALL         2
               1,  AT,O,E,SK,T,DT,X,PR,XMAX,THAX,DX,DV,TPRINT,DTPRNT,IMOVE,JMETH ALL       3
               2,  TSHFT,REPORT,OPPCT,TO,XO,XOISCH,ICHNG,XCHNG,TCHNG           ALL         4
000002          EQUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)                        ALL         5
000002          COMMON/MONEY/ JMMHM,DJM,OJMMH,DJMRD,DJMBMM,OMAINT,OJMBM,OJMGS  ALL         6
               1,  PMGS,JMCV,DJMEC,RDPLAN,HPLANT,GSPLAN                        ALL         7
               2,  ECPLAN,PDTIME,HTIME(2),GSTIME,ECTIME                        ALL         8
000002          COMMON/PERFRM/ RDUTIM,RODTIM,UMHTIM,OMHTIM,GSUTIM,GSOTIM,ECUTIM ALL        9
               1,  ECDTIM,GDAY,GADV,GENO,GBEG                                  ALL        10
000002          COMMON/LABOR/ ROMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2) ALL        11
000002          REAL JMMHM,LD,LOB,LBIT,LBURN,LSTEEL,JMCV                       ALL        12
000002          DIMENSION G(8)                                                 ALL        13
000002          EQUIVALENCE (G,XT),(XE,XDE),(PR,PC)                            ALL        14
000002          EQUIVALENCE (DTM,OTMA)                                         RAILMT     11
000002          DATA NTMA /0/                                                  RAILMT     12
000002          DATA MTINIT /0/                                                RAILMT     13
000002          DIMENSION RTIME(25)                                            RAILMT     14
000002          ENTRY TRUKMT                                                   RAILMT     15
000007          IF (MTINIT) 100,100,200                                        RAILMT     16
          C                             FIRST CALL TO SUBROUTINE               RAILMT     17
000011      100 IF ( TMAINT * JMMHM * OTM .GT. 0. ) GO TO 150                  RAILMT     18
          C                             HERE FOR OPTION 2  (VALUES TEMPORARY)  RAILMT     19
000015          TMAINT = 1.5                                                   RAILMT     20
000016          JMMHM = 100.                                                   RAILMT     21
000017          OTM = 20.                                                      RAILMT     22
000020      150 CONTINUE                                                       RAILMT     23
000020          MTINIT = 1                                                     RAILMT     24
000021          DO 170 I=1,25                                                  RAILMT     25
000023          RTIME(I) = TMAINT                                              RAILMT     26
```

```
000025      170 CONTINUE
000026          NTMA = 0
000027          PRINT 180, TMAINT, JMMHM, DTM
000041      180 FORMAT (43HORAIL MAINT. PARAMETERS - TIME TO REPAIR = ,F8.2,
               *        21H COST OF MATERIALS = ,F8.2,23H DAYS BETWEEN MAINT. = ,
               *        F8.2 )
              C                            IS IT TIME FOR MAINTENANCE
000041      200 NCOUNT = 0
000042          DO 400 I=1,NTRAIN
000044          IWRK = ITSTAT(I,1)
000046          IF (IWRK .EQ. 11) GO TO 300
000050          IF (IWRK .NE. 10) GO TO 400
              C                            TRAIN IS IN DISCHARGE AREA
000052          IF (TSTAT(I,4) .LT. DTM) GO TO 400
000055          IF (NTMA .GE. NTM) GO TO 400
              C                            TRAIN I NEEDS MAINTENANCE
000060          LTSTAT(I,1) = 11
000061          NTMA = NTMA + 1
000062          NTDA = NTDA - 1
000063          IF (NTDA .LT. NTD) LIFILD = 0
000066      300 RTIME(I) = RTIME(I) - DT
000071          NCOUNT = NCOUNT + 1
000072          IF (RTIME(I).GT. 0.)  GO TO 400
              C                            MAINTENANCE FINISHED
000075          IF (LIFILD .EQ. 1)  GO TO 400
000076          LTSTAT(I,1) = 10
000077          FTSTAT (I,4) = 0.
000100          DJMMH = DJMMH + JMMHM
000102          RTIME(I)= TMAINT
000104          NTMA = NTMA - 1
000105          NTDA = NTDA + 1
000106          IF (NTDA .GE. NTD) LIFILO = 1
000111          NCOUNT = NCOUNT - 1
000113      400 CONTINUE
000116          NTMA = NCOUNT
000117          IF (NTMA .GT. NTM) GO TO 500
000122          RETURN
000122      500 PRINT 550, NTMA,NTM
000132      550 FORMAT (1X,I4,40H TRAINS IN MAINTENANCE AREA. CAPACITY = ,I4)
000132          CALL EXIT
000133          END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
NTRUCK
LTRAIN
LTRUCK
IFILD
IFILLD
LNTRDA
LLTRAN
LLTRUK
LNTRAN
LNTRUK
IMOVE
JMETH
XT
```

```
XDE
PC
DTMA
NVEHCL
LVEHCL
LLVHCL
LNVHCL
JMOVE
IMETH
XE
PR
```

R. SUBROUTINE GRNSUP

```
GOLETA FORTRAN 1.3 * AUTO RFL * (07-12-72)                                        07/25/72

              SUBROUTINE GRNSUP                                          GRNSUP
         C                                                               GRNSUP
         C         ELEMENT-PRIMARY GROUND SUPPORT                        GRNSUP
         C         GENERAL PROCESS-ROCKBOLTS,STEEL RIB SETS,SHOTCRETE,COMBINATION GRNSUP
         CS OF THOSE                                                     GRNSUP
         C         ACTIVITY-INSTALLATION                                 GRNSUP
         C                                                               GRNSUP
000002        COMMON /GRND/ PSST(60,9),MAXPSST, UCS,UCSC,RATERB,RATESC,RATESS SUPPORT
             1,  GSLOS,TAS,TST,ERRDRT,ESCPLA,GDOW,GSETDO,MAXPSS          SUPPORT
000002        COMMON /WHEELS/ AF,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,DE,DF,DTAS WHEELS
             1,  OTMA,DTU,FL,FC,FR,FT,HPA,HPFA,HPEV,HPFA,HPFV,HPV,LOCO,MC,ML  WHEELS
             2,  NCARS,NPOINT,NTO,NTM,NTMAX,XP,NTMILP,NTMLPP,NIRACK,SL   WHEELS
             3,  TCURVX(20),TCURVY(20),TMAINT,TWE,VO,VS,VE,VF,VMAX,WC,WL,XDS  WHEELS
             4,  MAXLD,NUMLD,LOUF,QUC,WUC,STATUS(36),WHY(24),MLTYP,WMR,ECONEQ, WHEELS
             5   ECONSS,FLOCO,FMUCKC,FTRACK,ESWITC,FUNLOA,FRMAIN,11BORF, WHEELS
             6   1SW(25),NTINIT,TCCV,TMCV                                WHEELS
000002        COMMON /OLOCOM/ IFILO,KSTOP(25),KUNLO,LSTOP,LVFHCL,NBYBY,NSWCH WHEELS
             1,  NTPDA,NVEHCL,NUMSWT,SWITCH(20),TFC(25),TOP(25),TSTAT(25,4) WHEELS
             2,  UTTME(25),LOADP,MUKOT,XGS,1EXCA,MGS(5),MCV,MFLAGC,OUMMY(20) WHEELS
000002        COMMON /NEWCOM/ LIFILO,LKSTOP(25),LKUNLO,LLSTOP,LLVHCL,LNBYBY  WHEELS
             I,  LNSWCH,LNTRDA,LNVHCL,LNMSWT,FSWTCH(20),FTFC(25),FTOP(25) WHEELS
             2,  FTSTAT(25,4),FUTIMF(25),LLOADR,LMUKOT,FXGS,LIFXCA,LMGS(5) WHEELS
             3,  LMCV,LMFLAC,FOUMMY(19)                                  WHEELS
000002        OIMENSION COMOLD(260),COMNEW(260),LTSTAT(25,4),ITSTAT(25,4) WHEELS
000002        EQUIVALENCE (NVEHCL,NTRAIN,NTRUCK),(LVEHCL,LTRAIN,LTRUCK)  WHEELS
             1,  (COMOLD,1FTLD),(COMNEW,LIFILD,1FILLD),(NTDA,LNTRDA)     WHEELS
             2,  (FTSTAT,LTSTAT),(TSTAT,1TSTAT)                          WHEELS
             3,  (LLVHCL,LLTRAN,LLTRUK),(LNVHCL,LNTRAN,LNTRUK)           WHEELS
000002        OATA PSST / 95.,90.,90.,75.,75.,75.,50.,50.,50.,25.,25.,25.,0.,0., GRNSUP
             1 0.,45*0.,                                                 GRNSUP
             2 2*5.,2.,5.,1.,2.,5.,1.,2.,5.,1.,2.,5.,1.,2.,45*0.,        GRNSUP
             3 999999.,999993.,10.,8.,8.,5.,6.,6.,4.,5.,5.,3.,2.,2.,2.,45*0., GRNSUP
             4 4*0.,4.,5*0.,4.,2*0.,4.,46*0.,                            GRNSUP
             6 1.,1.,3.,3.,3.,2.,3.,3.,4.,3.,5*4.,45*0.,                 GRNSUP
             7 5*0.,5.,0.,0.,4.,0.,3.,3.,3*2.,45*0.,                     GRNSUP
             8 0.,0.    ,5.,2*1.,0.,2*3.,0.,5.,5*0.,45*0.,               GRNSUP
             9 0.,0.,0.,0.,0.,0.,0.,0.,0.,1.,0.,0.,0.,0.,0.,45*0.,       GRNSUP
             A 1.,1.,1.,1.,1.,1.,1.,1.,1.,2.,2.,1.,1.,1.,1.,45*0./       GRNSUP
000002        OATA MAXPS/15/                                             GRNSUP
000002        COMMON /ALL   / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG            ALL
             I,  AT,O,F,SK,T,OT,X,PR,XMAX,TMAX,OX,OV,TPRINT,DTPRNT,IMOVE,JMETH ALL
             2,  TSHFT,REPORT,OPPCT,TO,XO,XOISCH,TCHNG,XCHNG,TCHNG        ALL
000002        EQUIVALENCE (JMOVE,IMOVE),(IMETH, JMETH)                    ALL
000002        COMMON/MONEY/ JMMHM,DJM,DJMMH,OJMRO,OJMRMM,DMAINT,OJMBM,DJMGS ALL
             1,  PMGS,JMCV,DJMEC,RDPLAN,HPLANT,GSPLAN                     ALL
             2,  ECPLAN,RDTIME,HTIMF(2),GSTIMF,ECTIME                     ALL
000002        COMMON/PERFRM/ ROUTIM,RDOTIM,UMHTIM,OMHTIM,GSUTIM,GSOTIM,ECUTIM ALL
             1,  ECDTIM,GDAY,GAOV,GEND,GBEG                               ALL
000002        COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2) ALL
000002        REAL JMMHM,LD,LDB,LBIT,LBURN,LSTEEL,JMCV                    ALL
000002        DIMENSION G(8)                                              ALL
000002        EQUIVALENCE (G,XT),(XE,XDF),(PR,PC)                         ALL
000002        OIMENSION SSCOEF(9,3),WEIGSS1(11),WEIGSS2(11)               GRNSUP
         C                                                               GRNSUP
         C      PRE SETTING TABLES FOR STEEL RIB INSTALLATION            GRNSUP
```

```
        C
000002        DATA SSCOEF / 90.,75.,75.,50.,50.,25.,25.,0.,0.,5.,5.,2.,5.,2.,
             1 5.,2.,5.,2.,0.,2.,.45,.7,.95,.13,1.65,1.9,2.4/
000002        DATA WEIGSS1 /2.7330400,2.8032257,4.0346495,3.2721616,2.590875,
             13.6323957,3.7604603,6.4257773,3.5155762,3.113781,3.1443458/
000002        DATA WEIGSS2 / 1.8697457,2.0608183,1.9951426,2.3051969,2.5269964,
             1 2.5839495,2.7372833,2.8635011,3.2152662,3.4443974,3.6613087/
000002        DATA INIT,NEEDIN/0,0/
000002        DATA LMETH,ICS,MG,MAINT,IFST/5*0/
000002        DATA AL,TL,SP,SP1,TH,DIST,BPF,WRB/8*0./
000002        DATA TMETH,VSC,WRIB/3*0./
        C
        C       NOTE- GROUND SUPPORT TYPE =IST,ADDITIONAL SUPPORT =IAS
        C      IST,IAS ARE..
        C       1 IF NO SUPPORT REQUIRED
        C       2 IF ROCKBOLTS ARE BEING INSTALLED
        C       3 IF SHOTCRETE IS BEING INSTALLED
        C       4 IF STEEL RIB SETS ARE BEING INSTALLED
        C       5 IF LAGGING IS SUPPORT(ONLY IAS MAY =5)
        C
        C      FIRST TIME INITIALIZATION
        C
000002      5 PRINT 10
000006     10 FORMAT(//,1X,,28H      PRIMARY GROUND SUPPORT    )
000006        PRINT 11
000012     11 FORMAT(1X,* ROD   EXCAVATION   UNSUPPORTED   INTERFERENCE   SUPPOR
             1T   SPACING   THICKNESS   CROWN AND/   ADDITIONAL*)
000012        PRINT 12
000016     12 FORMAT(1X,*           PROCESS   LENGTH-MAXFT    LENGTH FT       TYP
             1E       FT            IN       OR SIDES       SUPPORT*)
000016        IF(MAXPSS .NE. 0) MAXPS=MAXPSS
000020        DO 14 I=1,MAXPS
000022        PRINT 13,(PSST(I,K),K=1,9)
000035     13 FORMAT (F7.2,F10.2,2F14.2,2F11.2,F10.2,2F13.2)
000035     14 CONTINUE
000040        PRINT 15
000043     15 FORMAT(1X,* NOTE. EXCAVATION PROCESS =5 INDICATES ANY PROCESS OTHE
             1R THAN THOSE IN TABLE*,//)
000043        FXGS=X
000045        INIT=1
000046         IF(NEEDIN .EQ. 0) GO TO 3000
000047        NEEDIN=0
000047        GO TO 6
        C
        C        INTIIALIZATION EACH ENTRANCE
        C
000050        ENTRY GROUN
000055        IF(INIT .NE. 0) GO TO 6
000056        NEEDIN=1
000057        GO TO 5
000060      6 MAINT=0
000061        ADV=0.
000062        DPMGS=0.
000063        ADVLOS=0.
000064        PMGLOS=0.
```

```
000065          LAB=0
000066          WRIB=0.
000067          IFST=0.
000070          WRB=0.
000071          BPF= 0
000072          SP=0
000073          VSC=0
000074          DO 25 I=1,MAXPS
000075           IF (PSST(I,1) .LE. RQD) GO TO 30
000100       25 CONTINUE
000103       30 IP=I
000105          DO 35 I=IP,MAXPS
000106           IF(PSST(I,1) .NE. PSST(IP,1)) GO TO 36
000111          IPPST=PSST(I,2)
000114          IF (IPPST.EQ.JMETH) GOTO 40
000116       35 CONTINUE
000120       36 IQ=I
000122          DO 37 J=IP,IQ
000124           IF(PSST(J,2)  .EQ. 5)    GO TO 39
000127       37 CONTINUE
000132          GO TO 1800
000132       39 IP=J
000134           GO TO 42
000134       40 IP=1
000136       42 LMETH=PSST(IP,2)
000141          TMETH=JMETH
000143          AL=PSST(IP,3)
000144           TL=PSST(IP,4)
000146          IST=PSST(IP,5)
000150          SP=PSST(IP,6)
000152          TH=PSST(IP,7)
000153          ICS=PSST(IP,8)
000156          IAS=PSST(IP,9)
000160          MG=MGS(IST)
           C
           C      STATUS CHECK FOR GROUND SUPPORT
           C
000162          DIST=X-XGS
000164          IF(IEXCA .EQ. 0) GO TO 43
000165          IF(DIST .LE. TL) LIEXCA=0
000171       43 IF(DIST .GT. AL) LIEXCA=1
000175          IF(DIST .LT. TL) MAINT=1
           C
           C
           C      COMPUTING LABOR TIME USED FOR THIS ACTIVITY
           C
000201          GSTIME=GSTIME+DT
           C       COMPUTING MATERIALS FOR GROUND SUPPORT
000203          GO TO(1000,200,300,400,500),IST
           C
           C      COMPUTING GROUND SUPPORT USING ROCK BOLTS
           C
000214      200 IF(MG .EQ. 1) MAINT=1
000217          BPF=3.1415*D/(2*.866*(SP)**2)
000224          WRB=.284*3.1415*D
```

```
000226          GO TO 1000
          C
          C       COMPUTING GROUND SUPPORT USING SHOTCRETE
          C
000226      300 IF(MG .EQ. 1) MAINT=1
000231          IF (RQD .LE. 25.) GO TO 1900
000234          IF (ICS .EQ. 1) GO TO 306
000236          VSC=3.1415*D*TH/(324.*2.)
000241          GO TO 310
000242      306 VSC=3.*3.1415*D*TH/(324.*4.)
000246      310 GO TO 1000
          C
          C       COMPUTING GROUND SUPPORT USE OF STEEL RIBS
          C
000247      400 IF(MG .EQ. 1) MAINT=1
000252          DO 410 I=1,9
000254           IF (SSCOEF(I,1) .LE. RQD) GO TO 415
000257      410 CONTINUE
000261      415 IP=I
000263          IF(SSCOEF(IP+1,2) .EQ. TMETH) IP=IP+1
000270          PLOAD=SSCOEF(IP,3) *D*SP*CS
000275          DO 420 I=1,11
000276          PK=(I+6)*2+1
000301          IF(D .LE. PK) GO TO 422
000304      420 CONTINUE
000306          GO TO 1950
000306      422 SSWEIG=WEIGSS2(I)*(10.**-3)*PLOAD+WEIGSS1(I)
000315      430 WPIB=3.1415*D*SSWEIG
000320      500 GO TO 1000
          C
          C       DETERMINING WHICH COST CALCULATION TO USE
          C
          C
          C       DETERMINING ADDITIONAL SUPPORT COMPUTATIONS
          C
000321     1000 IF(IFST .EQ. 1) GO TO 1050
000323          IFST=1
000324          SP1=SP
000326          MG=MGS(IAS)
000330          GO TO(1050,1020,1030,1040,1050) ,IAS
          C
          C       WITH ADDITIONAL SUPPORT = ROCK BOLTS SET UP ROCKBOLT COMPUTATIONS
          C
000340     1020 IF(IST .NE. 3) GO TO 1025
000342          IF(RQD .GT. 50.) GO TO 1050
000346          SP=5.
000347          GO TO 200
000347     1025 IF(IST .NE. 4) GO TO 1028
000351          SP=5.
000353          GO TO 200
000353     1028 IF(SP .EQ. 0.) SP=5.
000355          GO TO 200
          C
          C       ADDITIONAL SUPPORT = SHOTCRETE SET UP FOR SHOTCRETE COMPUTATIONS
          C
```

```
000356    1030 IF(TH . EQ. 0.) TH=.5*D
000361         GO TO 300
          C
          C      ADDITIONAL SUPPORT=STEEL RIBS SET UP STEEL RIBS COMPUTATION
          C
000362    1040 IF(IST .NE. 2) GO TO 1045
000364         SP=4.
000366         GO TO 400
000366    1045 IF(SP .EQ. 0.) SP=4.
000370         GO TO 400
          C
          C      DETERMINING WHICH COST CATEGORY TO USE
          C
000371    1050 IF((IAS .NE. 5) .AND. (IAS .NE. 1)) GO TO 1060
000401         GO TO (1100,1200,1300,1400 ) , IST
000411    1060 IF(IAS .NE. 2) GO TO 1070
000413         GO TO (1200,1200,1500,1600,1200),IST
000424    1070 IF(IAS .NE. 3) GO TO 1080
000426         GO TO (1300,1500,1300,1700,1300) ,IST
000437    1080 IF(IAS .NE. 4) GO TO 1090
000441         GO TO (1400,1600,1700,1400,1400) ,IST
000452    1090 GO TO 1825
          C
          C      COMPUTING ADVANCE AND COST WITH NO SUPPORT
          C
000453    1100 FXGS=X-TL
000455         GO TO 2000
          C
          C      COMPUTING ADVANCE AND COST WITH ROCK BOLTS
          C
000456    1200 ADV=RATERB*DT/RPF
000461         FXGS=ADV+XGS
000463         RBLBS=ADV*RPF*WRB
000465         DPMGS=RBLBS*UCS
000467         PMGS=PMGS+DPMGS
000470         GO TO 2000
          C
          C      COMPUTING ADVANCE AND COST USING SHOTCRETE
          C
000471    1300 ADV=RATESC*DT/VSC
000474         FXGS=XGS+ADV
000476         CUYD=ADV*VSC
000477          DPMGS=CUYD*UCSC
000501         PMGS=PMGS+DPMGS
000502         GO TO 2000
          C
          C      COMPUTING ADVANCE AND COST USING STEEL RIBS
          C
000503    1400 ADV=RATESS*DT*SP
000506         FXGS=XGS+ADV
000510         SRLBS=(ADV/SP)*WRIB
000512         DPMGS=SRLBS*UCS
000514         PMGS=PMGS+DPMGS
000515         GO TO 2000
          C
```

```
              C       COMPUTING ADVANCE AND COST USING SHOTCRETE AND ROCK BOLTS
              C
000516         1500 ADV=(RATERB/RPF+RATESC/VSC)*DT/2
000524              FXGS=XGS+ADV
000526              CUYD=ADV*VSC
000527              RBLBS=ADV*RPF*WRB
000531              OPMGS=CUYD*UCSC    +RBLBS*UCS
000535              PMGS=PMGS+OPMGS
000536              GO TO 2000
              C
              C       COMPUTING COST AND ADVANCE USING STEEL RIBS AND ROCK BOLTS
              C
000537         1600 IF(IST .EQ. 4) SP=SP1
000543              ADV=(RATESS*SP+RATERB/RPF)*DT/2.
000551              FXGS=XGS+ADV
000553              SRLBS=(ADV/SP)*WRIB
000556              RBLBS=ADV*RPF*WRB
000560              OPMGS=(SRLBS+RBLBS)*UCS
000563              PMGS=PMGS+OPMGS
000564              GO TO 2000
              C
              C       COMPUTING ADVANCE AND COST USING SHOTCRETE AND STEEL RIBS
              C
000565         1700 ADV=(RATESC/VSC+RATESS*SP)*DT/2.
000573              FXGS=XGS+ADV
000575              CUYD=ADV*VSC
000577              SRLBS=(ADV/SP)*WRIB
000601              OPMGS=CUYD*UCSC+SRLBS*UCS
000604              PMGS=PMGS+OPMGS
000606              GO TO 2000
              C
              C         ERROR MESSAGES
              C
000606         1800 PRINT 1801
000612         1801 FORMAT(/1X,* UNABLE TO PERFORM GROUND SUPPORT,CANNOT FIND EXCAVATI
                   1ON METHOD IN PSST TABLE AND NOOTHER METHOD IS IN TABLE*)
000612              GO TO 1975
000613         1825 PRINT 1826,IAS
000621         1826 FORMAT(//1X,* ADDITIONAL SUPPORT *,I5,* IS NONEXISTANTIN PROGRAM*)
000621              GO TO 1975
000622         1900 PRINT 1901
000626         1901 FORMAT(1X,75H UNABLE TO PERFORM SUPPORT,SHOTCRETE CANNOT BE USED 1
                   1F ROD IS LESS THAN 25         )
000626              GO TO 1975
000627         1950 PRINT 1951
000633         1951 FORMAT(85HUNABLE TO PERFORM SUPPORT STEEL RIB WEIGHT INDETERMINATE
                   1 FOR DIAMETER GREATER THAN 34         )
000633         1975 FXGS=XGS
000635              FRACT=0.
000636              STOP
              C
              C       COMPUTING ACTUAL GROUND SUPPORT IF TOO CLOSE TO FACE OR BEYOND
              C
000640         2000 DIST1=X-TL
000642              FRACT=1.
```

```
000644         IF(MAINT .EQ. 1) GO TO 2500
000646         IF (FXGS .LE. DIST1) GO TO 2005
000650         FRACT=(DIST1-XGS)/ADV
000653         ADV=DIST1-XGS
000654         ADVLOS=FXGS-(X-TL)
000657         GSLOS=GSLOS+ADVLOS
000660         FXGS=XGS+ADV
000662          PMGLOS=DPMGS*(1.-FRACT)
000665         PMGS=PMGS-PMGLOS
000667    2005 GO TO 3000
        C
        C       COMPUTING FEET LOST FOR GROUND SUPPORT IF IN MAINTENANCE OR IF ID
        C      LE FOR ALL OT
        C
000670    2500 PMGS=PMGS-DPMGS
000672         GSLOS=GSLOS+(FXGS-XGS)
000675         FXGS=XGS
000676         FRACT =0
000676    3000 CONTINUE
        C
        C       COMPUTING UP TIME OF GROUND SUPPORT
        C
000676         GSUTIM=GSUTIM+FRACT*OT
        C
        C       COMPUTING PLANT AND EQUIPMENT COSTS
        C
000701         IF((IST .EQ. 2) .OR. (IAS .EQ. 2)) GO TO 3025
000711         IF((IST .NE. 3) .AND. (IAS .NE. 3)) GO TO 3050
000717         IF((IST .EQ. 5) .OR. (IAS .EQ. 5)) GO TO 3015
000725         IF((IST .EQ. 1) .OR. (IAS .EQ. 1)) GO TO 3015
000733         OTT=OT/2.
000735         GO TO 3020
000735    3015 OTT=OT
000737    3020 GSPLAN=GSPLAN+OTT*FRACT*ESCPLA
000743         GO TO 3050
000744    3025 IF((IST .EQ. 5) .OR. (IAS .EQ. 5)) GO TO 3027
000754         IF((IST .EQ. 1) .OR. (IAS .EQ. 1)) GO TO 3027
000762         DTT=OT/2.
000764         GO TO 3030
000764    3027 DTT=OT
000766    3030 GSPLAN=GSPLAN+OTT*FRACT*ERRORI
000772         IF((IST .EQ. 3) .OR. (IAS .EQ. 3)) GO TO 3015
001002    3050 CONTINUE
001002         RETURN
001003         END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
NTRAIN
NTRUCK
LTRAIN
LTRUCK
IFILO
LIFILD
IFILLD
LNTROA
LLTRAN
```

```
LLTRUK
LNTRAN
LNTRUK
IMOVE
XT
XDE
PC
NVEHCL
LVEHCL
NTDA
LLVHCL
LNVHCL
JMOVE
IMETH
XE
PR
```

S. SUBROUTINE GSMAIN

```
GOLETA FORTRAN 1.3 * AUTO RFL * (07-12-72)                                               07/25/72

                 SUBROUTINE GSMAIN                                              GSMAIN     2
            C                                                                   GSMAIN     3
            C        FLEMENT-PRIMARY GROUND SUPPORT                             GSMAIN     4
            C        GENERAL PROCESS-ROCKBOLTS,STEEL RIB SETS,SHOTCRETE,COMBINATION GSMAIN  5
            CS OF THOSE                                                         GSMAIN     6
            C        ACTIVITY-MAINTENANCE                                       GSMAIN     7
            C                                                                   GSMAIN     8
000002           COMMON /GRND/ PSST(60,9),MAXPSST, UCS,UCSC,RATERB,RATESC,RATESS  SUPPORT   2
               1,  GSLOS,IAS,IST,ERBDRI,FSCPLA,GDOW,GSFTOO,MAXPSS               SUPPORT    3
000002           COMMON /WHEELS/ AF,AF,AMAX,AMAXL,AMINL,BSL,CARCAP,CP,DF,DF,DTAS  WHEELS   2
               I,  DTMA,DTU,FL,FC,FR,FT,HPA,HPEA,HPEV,HPFA,HPFV,HPV,LOCO,MC,ML  WHEELS     3
               2,  NCARS,NPOINT,NTD,NTM,NTMAX,XP,NTMILP,NTMLPP,NTRACK,SL        WHEELS     4
               3,  TCURVX(20),TCURVY(20),THAINT,TWE,VO,VS,VE,VF,VMAX,WC,WL,XOS  WHEELS     5
               4,  MAXLD,NUMLD,LOUE,QUC,WUC,STATUS(36),WHY(24),MLTYP,WMR,ECONEQ, WHEELS    6
               5   ECONSS,FLOCD,EMUCKC,ETRACK,ESWITC,EUNLOA,ERMAIN,IIBORE,      WHEELS     7
               6   ISW(25),NTINIT,TCCV,TMCV                                     WHEELS     8
000002           COMMON /OLDCOM/ IFILD,KSTOP(25),KUNLO,LSTOP,LVEHCL,NBYBY,NSWCH  WHEELS    9
               1,  NTRDA,NVEHCL,NUMSWT,SWITCH(20),TFC(25),TOP(25),TSTAT(25,4)   WHEELS    10
               2,  UTIME(25),LOADR,MUKOT,XGS,IEXCA,MGS(5),MCV,MFLAGC,OUMMY(20)  WHEELS    11
000002           COMMON /NEWCOM/ LIFILO,LKSTOP(25),LKUNLO,LLSTOP,LLVHCL,LNBYBY  WHEELS    12
               1,  LNSWCH,LNTRDA,LNVHCL,LNMSWT,FSWTCH(20),FTFC(25),FTOP(25)     WHEELS    13
               2,  FTSTAT(25,4),FUTIME(25),LLOADR,LMUKOT,FXGS,LIEXCA,LMGS(5)    WHEELS    14
               3,  LMCV,LMFLAC,FDUMMY(I9)                                       WHEELS    15
000002           OIMENSION COMOLO(260),COMNEW(260),


                                                  LTSTAT(25,4),ITSTAT(25,4)      WHEELS    16
000002           EQUIVALENCE (NVEHCL,NTRAIN,NTRUCK),(LVEHCL,LTRAIN,LTRUCK)      WHEELS    17
               1,  (COMOLD,IFILO),(COMNEW,LIFILD,IFILLO),(NTOA,LNTROA)          WHEELS    18
               2,  (FTSTAT,LTSTAT),(TSTAT,ITSTAT)                               WHEELS    19
               3,  (LLVHCL,LLTRAN,LLTRUK),(LNVHCL,LNTRAN,LNTRUK)                WHEELS    20
000002           COMMON /ALL    / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG              ALL        2
               1,  AT,D,E,SK,T,DT,X,PR,XMAX,TMAX,OX,DV,TPRINT,DTPRNT,IMOVE,JMETH ALL       3
               2,  TSHFT,REPORT,OPPCT,TO,XO,XOISCH,ICHNG,XCHNG,TCHNG            ALL        4
000002           EQUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)                        ALL        5
000002           COMMON/MONEY/ JMMHM,DJM,OJMMH,OJMRD,OJMBMM,OMAINT,DJMBM,DJMGS  ALL        6
               1,  PMGS,JMCV,DJMFC,RDPLAN,HPLANT,GSPLAN                         ALL        7
               2,  ECPLAN,RDTIME,HTIME(2),GSTIMF,ECTIME                         ALL        8
000002           COMMON/PERFRM/ RDUTIM,RDDTIM,UMHTIM,DMHTIM,GSUTIM,GSOTIM,ECUTIM ALL       9
               1,  ECDTIM,GDAY,GADV,GEND,GBEG                                   ALL       10
000002           COMMON/LABOR/ RDMFN(I0,2),MMEN(10,2,2),GSMEN(10,2),ECMEN(10,2) ALL       11
000002           REAL  JMMHM,LD,LOB,LBIT,LBURN,LSTEEL,JMCV                      ALL       12
000002           OIMENSION G(8)                                                 ALL       13
000002           EQUIVALENCE (G,XT),(XE,XOE),(PR,PC)                            ALL       14
000002           OIMENSION GSMT(S),DOWNT(5), GOOWN(S),SETDOW(S)                 GSMAIN    12
000002           DATA GSMT/ 5*0./                                               GSMAIN    13
000002           OATA DOWNT/5*0./                                               GSMAIN    14
000002           DATA GDOWN/5*7.5/                                              GSMAIN    15
000002           DATA SETDOW/5*.5/                                              GSMAIN    16
000002           OATA INC/I/                                                    GSMAIN    17
000002           OATA INIT,NEEDIN/0,0/                                          GSMAIN    18
            C                                                                   GSMAIN    19
            C        NOTE- GROUND SUPPORT TYPE =IST,AOOITIONAL SUPPORT =IAS     GSMAIN    20
            C       IST,IAS ARE..                                               GSMAIN    21
            C        1 IF NO SUPPORT REQUIRED                                   GSMAIN    22
            C        2 IF ROCKBOLTS ARE BEING INSTALLED                         GSMAIN    23
            C        3 IF SHOTCRETE IS BEING INSTALLED                          GSMAIN    24
            C        4 IF STEEL RIB SETS ARE BEING INSTALLED                    GSMAIN    25
```

```
        C       S IF LAGGING IS SUPPORT(ONLY IAS MAY =5)
        C
000002        1 INIT=1
000003          DO 4 J=1,5
000005          IF(GDOW .NE. 0.) GDOWN(J)=GDOW
000007          IF(GSETDO .NE. 0.) SETDOW(J)=GSETDO
000012        4 CONTINUE
000014          IF (NEEDIN .EQ. 0) GO TO 150
000015          NEEDIN=0
000016          GO TO 5
        C        NORMAL ENTRY
000016          ENTRY GSMNT
000023          IF(INIT .EQ. 1) GO TO 5
000025          NEEDIN=1
000026          GO TO 1
000027        5 IF((IAS .NE. 1) .AND. (IAS .NE. 5)) INC=2
000040          DO 110 I=2,4
000042          DOWN=DOWNT(I)
000044          GSM=GSMT(I)
000045          MG=MGS(I)
        C
        C        DETERMINING IF GROUND SUPPORT TYPE I IS IN USE DURING DT
        C
000047          IF((I .EQ. IST) .OR. (I .EQ. IAS)) GO TO 50
        C
        C        DETERMINING IF GROUND SUPPORT TYPE I IS IN MAINTENANCE
        C
000056          IF(MG .EQ. 0) GO TO 100
        C
        C        REDUCING MAINTENANCE TIME BY DT FOR GROUND SUPPORT TYPE I
        C
000057       25 DOWN =DOWN-DT
000061          IF(DOWN .GT. 0.) GO TO 100
        C
        C        REMOVING GROUND SUPPORT TYPE I FROM MAINTENANCE
        C
000063          DOWN=0.
000063          LMG=0
000064          GO TO 100
000064       50 IF(MG .EQ. 1) GO TO 25
000066          GSM=GSM+DT/INC
        C
        C         DETERMINING IF GROUND SUPPORT TYPE I IS DUE FOR MAINTENANCE
        C
000072          IF(GSM .LE. GDOWN(I)) GO TO 100
        C
        C         PUTTING GROUND SUPPORT TYPE I INTO MAINTENANCE
        C
000075          LMG=1
000076          DOWN=SETDOW(I)
000077          PMGS=PMGS+DJMGS
000101          GSM=0.
000102          GSDTIM=GSDTIM+DOWN
000104      100 DOWNT(I)=DOWN
000106          GSMT(I)=GSM
```

```
      LMGS(I)=LMG
  110 CONTINUE
  150 CONTINUE
      RETURN
      END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
NTRAIN
NTRUCK
LTRAIN
LTRUCK
IFILD
LIFILD
IFILLD
LNTRDA
LLTRAN
LLTRUK
LNTRAN
LNTRUK
IMOVE
JMETH
XT
XDE
PC
NVEHCL
LVEHCL
NTDA
LLVHCL
LNVHCL
JMOVE
IMETH
XE
PR
```

T. SUBROUTINE ENVIR

```
GOLETA FORTRAN 1.3 * AUTO RFL * (07-12-72)                                               07/25/72

              SUBROUTINE ENVIR                                                   ENVIR        2
         C                                                                       ENVIR        3
         C    ELEMENT - ENVIRONMENTAL CONTROL                                    ENVIR        4
         C    GENERAL PROCESS - VENTILATION + COOLING                            ENVIR        5
         C    ***#HEAT# MUST BE RETRIEVED FROM ROCK DISINTEGRATION ROUTINE       ENVIR        6
         C    ***#TROCK#  #        #          #   TUNNEL FILE INPUT              ENVIR        7
         C                                                                       ENVIR        8
000002        COMMON /ALL   / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG                   ALL          2
             1,  AT,D,E,SK,T,OT,X,PR,XMAX,TMAX,DX,DV,TPRINT,DTPRNT,IMOVE,JMETH   ALL          3
             2,  TSHFT,REPORT,OPPCT,TD,XO,XDISCH,ICHNG,XCHNG,TCHNG               ALL          4
000002        EQUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)                            ALL          5
000002        COMMON/MONEY/ JMMHM,DJM,DJMMH,DJMRD,DJMBMM,DMAINT,DJMBM,DJMGS      ALL          6
             1,  PMGS,JMCV,DJMEC,RDPLAN,HPLANT,GSPLAN                            ALL          7
             2,  ECPLAN,RDTIME,HTIME(2),GSTIME,ECTIME                            ALL          8
000002        COMMON/PERFRM/ ROUTIM,RDDTIM,UMHTIM,DMHTIM,GSUTIM,GSDTIM,ECUTIM    ALL          9
             1,  ECDTIM,GDAY,GADV,GEND,GBEG                                      ALL         10
000002        COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2)     ALL         11
000002        REAL JMMHM,LO,LOB,LBIT,LBURN,LSTEEL,JMCV                           ALL         12
000002        DIMENSION G(8)                                                     ALL         13
000002        EQUIVALENCE (G,XT),(XE,XDE),(PR,PC)                                ALL         14
000002        COMMON /ENVC/ MAXMEN,TOTHP,QM,QD,VAMIN,VAMAX,QG(10),               ENVIRON      2
             1    TA,TO,WA,FKD,FKT,CPA,CKA,REFRAT,AMC(10),QDR,EVENTP,CPUMP       ENVIRON      3
000002        EQUIVALENCE (TROCK,TAMB),(HEAT,HEATJ)                              ENVIR       11
000002        DIMENSION QDG(10)                                                  ENVIR       12
000002        DATA INIT /0/                                                      ENVIR       13
000002        DATA NEEDIN /0/                                                    ENVIR       14
000002        DATA PI /3.1415927/                                                ENVIR       15
000002        DATA DFACT,VFACT,QMP,QDHP,QAV,QDR /6*0./                           ENVIR       16
000002        DATA FACT1,FACT2,FACT3,FACT4,TAVELM /5*0./                         ENVIR       17
000002        DATA FACT2A /0./                                                   ENVIR       18
000002        DATA QDS /10*0./                                                   ENVIR       19
         C                                  INITIALIZATION                       ENVIR       20
         C                                                                       ENVIR       21
000002     10 DJMEC = 0.                                                         ENVIR       22
000003        ECDTIME=0.                                                         ENVIR       23
000004        ECUTIME=0.                                                         ENVIR       24
000005        IF (QM .EQ. 0.) QM = 200.                                          ENVIR       25
000007        IF (QD .EQ. 0.) QD = 106. + 0.334 * TOTHP                          ENVIR       26
000013        IF (VAMIN .EQ. 0.) VAMIN = 50.                                     ENVIR       27
000015        IF (VAMAX .EQ. 0.) VAMAX = 1000.                                   ENVIR       28
000017        IF (TO .EQ. 0.) TO = 80.                                           ENVIR       29
000021        IF (WA .EQ. 0.) WA = 0.075                                         ENVIR       30
000023        IF (FKD .EQ. 0.) FKD = 2.0E-9                                      ENVIR       31
000025        IF (FKT .EQ. 0.) FKT = 1.5E-8                                      ENVIR       32
000027        IF(CPA .EQ. 0.) CPA = 0.240                                        ENVIR       33
000031        IF (CKA .EQ. 0.) CKA = 0.0147                                      ENVIR       34
000033        IF (REFRAT .EQ. 0.) REFRAT = 2.0E-6                                ENVIR       35
000035        IF (PR .EQ. 0.) PR = 0.015                                         ENVIR       36
000037        DFACT = D * PI / 4.                                                ENVIR       37
000042        VFACT = D * DFACT                                                  ENVIR       38
         C                            QMP = AIR VOLUME RATE REQUIRED BY MANPOWER ENVIR       39
000043        QMP = QM * MAXMEN                                                  ENVIR       40
         C                            QDHP = AIR VOL. RATE REQUIRED BY DIESEL HP ENVIR       41
000046        QDHP = QD * TOTHP                                                  ENVIR       42
         C                            QAV = AIR VOL. RATE REQUIRED BY AIR VELOCIT ENVIR      43
```

```
000050          QAV = VAMIN * VFACT                                         ENVIR
            C                            QDG(N) = AIR VOL. RATE REQUIRED BY DILUTION ENVIR
            C                                  OF GAS N                     ENVIR
000052          DO 50 I = 1,10                                              ENVIR
000053          IF (AMC(I) .EQ. 0.) GO TO 50                                ENVIR
000055          QDG(I) = 1.0E6 * DG(I) / AMC(I)                             ENVIR
000060       50 CONTINUE                                                    ENVIR
            C                            QDR = DESIGN REQUIREMENT AIR VOLUME RATE    ENVIR
000062          QDR = QHP                                                   ENVIR
000064          IF (QDHP .GT. QDR) QDR = QDHP                               ENVIR
000067          IF (QAV .GT. QDR) QDR = QAV                                 ENVIR
000072          DO 70 I = 1,10                                              ENVIR
000074          IF (QDG(I) .GT. QDR) QDR = QDG(I)                           ENVIR
000101       70 CONTINUE                                                    ENVIR
            C                            CHECK DESIGN REQUIREMENT VS ALLOWABLE AIR V ENVIR
000103          TAVEL = QDR / VFACT                                         ENVIR
000105          IF (TAVEL .LE. VAMAX) GO TO 95                              ENVIR
000107          PRINT 90, TAVEL,VAMAX                                       ENVIR
000117       90 FORMAT (33H0VENTILATION DESIGN REQUIREMENT, ,F14.3,43H,EXCEEDS ALL ENVIR
               *OWABLE AIR VELOCITY IN TUNNEL, ,F14.3,17H, RUN TERMINATED.  )  ENVIR
000117          CALL EXIT                                                   ENVIR
            C                            COMPLETE INITIALIZATION            ENVIR
000120       95 FACT1 = CKA / D                                             ENVIR
000122          FACT2 = PI * D                                              ENVIR
000124          FACT2A = FACT2 * (TA + 80.) / 2.                            ENVIR
000127          FACT3 = WA * CPA * 60.                                      ENVIR
000132          FACT4 = 1.3 * D                                             ENVIR
000134          TAVELM = TAVEL                                              ENVIR
000135          INIT = 1                                                    ENVIR
000136          IF (NEEDIN .EQ. 0) GO TO 999                                ENVIR
000137          NEEDIN = 0                                                  ENVIR
000140          GO TO 100                                                   ENVIR
            C                            NORMAL ENTRY                       ENVIR
000140          ENTRY ENVIRC                                                ENVIR
000145          TAVEL = TAVELM                                              ENVIR
000147          IF(INIT .EQ. 1) GO TO 97                                    ENVIR
000151          NEEDIN = 1                                                  ENVIR
000152          GO TO 10                                                    ENVIR
            C                                                               ENVIR
            C      COMPUTING LABOR TIME USED FOR THIS ACTIVITY              ENVIR
            C                                                               ENVIR
000152       97 ECTIME=ECTIME+DT                                            ENVIR
            C      NOTE ENVIR NEVER STOPS AT PRESENT THIS MAY BE CHANGED IN THE FUTU ENVIR
            C                                                               ENVIR
            C      COMPUTING UP TIME                                        ENVIR
            C                                                               ENVIR
000154          ECUTIM=ECUTIM+DT                                            ENVIR
            C                                                               ENVIR
            C      COMPUTING PLANT AND EQUIPMENT COSTS                      ENVIR
            C                                                               ENVIR
000156          ECPLAN=ECPLAN+DX*EVENTP                                     ENVIR
            C      CALCULATE COST OF PUMPING WATER OUT OF TUNNEL            ENVIR
000161          DJMEC=DJMEC+CPUMP*DT*60.*(FLOW+QWATR)                       ENVIR
            C      CALCULATE REYNOLDS NUMBER FOR TUNNEL AIL FLOW CONDITIONS ENVIR
000165      100 REYND=TAVEL*D/0.165                                         ENVIR
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```
000170          QDR = TAVEL * QFACT
          C                            DERIVE NUSSELT NO.
000172          IF (REYNO .GE. 10000.) GO TO 120
000174          IF (REYNO .LE. 2100.) GO TO 130
000177          RNUSS=5.0+(26.7*(REYNO-2100.)/7900.)
000203          GO TO 150
000203      120 RNUSS = 0.02 * REYNO ** 0.8
000210          GO TO 150
000210      130 RNUSS = 0.5 * REYNO ** 0.3
          C                            CALC HEAT TRANSFER COEFFICIENT
000215      150 HEATC = RNUSS * FACT1
          C                            CALC HEAT ADDED TO AIR FROM WALL SURFACE
000217          XWRK=HEATC*(X-XDISCH)
000222          QRFAC = (FACT2*XWRK*TROCK) - (XWRK*FACT2A)
          C                            CALC HEAT ADDED TO AIR FROM MACHINERY
000226          QMFAC = HEAT / DT
          C                            CALC TEMPERATURE AT TUNNEL FACE
000230          TDF= (QRFAC + QMFAC) / (FACT3 * QDR) + TA
000235          IF (TDF .LE. TD) GO TO 500
000237          IF (TAVEL + 100. .GT. VAMAX) GO TO 400
          C                            MAX VELOCITY NOT YET ACHIEVED
000244          TAVEL = TAVEL + 100.
000245          GO TO 100
          C                            CALC MECHANICAL REFRIGERATION LOAD
000245      400 QREFRG = QDR * FACT3 * (TDF - TD)
          C                            CALC OPERATING COST OF REFRIGERATION IN DT
000251          DJMEC = DJMEC + QREFRG * REFRAT * DT
          C                            SELECT SUITABLE VENT DUCT VELOCITY
000254      500 VDUCT = 2380. + 0.0483 * QDR
          C                            CALC FRICTION LOSS OF AIR FLOWING IN TUNNEL
000257          HTUN = (FKT * X * TAVEL * TAVEL) / FACT4
          C                            CALC VENT DUCT DIAMETER
000263          XWRK = QDR / (PI * VDUCT)
000266          DDUCT = 2. * SQRT (XWRK)
          C                            CALC FRICTION LOSS OF AIR IN VENT DUCT
000271          HDUCT = ( FKD* (X-XDISCH) * VDUCT * VDUCT )/( 1.3 * DDUCT )
          C                            CALC AIR HORSEPOWER
000277          PAIR = QDR * (HTUN + HDUCT) / 6350.
          C                            CALC FAN HORSEPOWER
000302          PFAN = PAIR / 0.75
          C                            CALC VENTILATION POWER COST DURING DT
000304          FKWHR = PFAN * 0.7452 * DT
000306          DJMEC = DJMEC + PR * FKWHR
000311          X1 = QREFRG * REFRAT * DT
000313          X2 = PR * FKWHR
000314      999 CONTINUE
000314          RETURN
000315          END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
IMOVE
JMETH
XT
XDE
PC
TAMB
```

```
JMOVE
IMETH
XE
```

U. SUBROUTINE MAXADV

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GOLETA FORTRAN 1.3 * AUTO RFL * (07-12-72)                                              07/25/72

                 SUBROUTINE MAXADV                                           REPORT     2
          C       COMPUTING ADVANCE EACH DAY IN FEET, STORING MAXIMUM        REPORT     3
          C                                                                  REPORT     4
000002           COMMON /ALL   / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG           ALL        2
                1,  AT,D,F,SK,T,OT,X,PR,XMAX,TMAX,DX,DV,TPRINT,DTPRNT,IMOVE,JMETH ALL   3
                2,  TSHFT,REPORT,OPPCT,TD,XO,XOISCH,ICHNG,XCHNG,TCHNG       ALL        4
000002           EQUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)                    ALL        5
000002           COMMON/MONEY/ JMMHM,DJM,DJMMH,DJMRD,DJMBMM,DMAINT,DJMBM,DJMGS ALL     6
                1,  PMGS,JMCV,DJMEC,RDPLAN,HPLANT,GSPLAN                    ALL        7
                2,  ECPLAN,RDTIME,HTIME(2),GSTIME,ECTIME                    ALL        8
000002           COMMON/PERFRM/ RDUTIM,RDOTIM,UMHTIM,DMHTIM,GSUTIM,GSOTIM,ECUTIM ALL   9
                1,  ECOTIM,GDAY,GADV,GENO,GBEG                              ALL       10
000002           COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2) ALL   11
000002           REAL JMMHM,LD,LDB,LBIT,LBURN,LSTEEL,JMCV                   ALL       12
000002           DIMENSION G(8)                                             ALL       13
000002           EQUIVALENCE (G,XT),(XE,XOE),(PR,PC)                        ALL       14
000002           DATA INIT,NEEDIN/2*0/                                      REPORT     6
000002           DATA OLDX,ROUT/2*0./                                       REPORT     7
          C        INITIALIZATION                                           REPORT     8
000002         I INIT=1                                                     REPORT     9
000003           IF (TSHFT .EQ. 0.) TSHFT=24.                               REPORT    10
000005           OLDX=X                                                     REPORT    11
000007           IF(NEEDIN .EQ. 0) GO TO 999                                REPORT    12
000010           NEEDIN=0                                                   REPORT    13
000010           GO TO 15                                                   REPORT    14
          C      NORMAL ENTRY                                               REPORT    15
000011           ENTRY MAXADW                                               REPORT    16
000016        10 IF(INIT .EQ. 1) GO TO 15                                   REPORT    17
000020           NEEDIN=1                                                   REPORT    18
000021           GO TO I                                                    REPORT    19
000022        15 RDUT=ROUTIM-ROUT                                           REPORT    20
000024           IF(RDUT .EQ. 0.) GO TO 999                                 REPORT    21
000025           ADVV=(X-OLDX)/RDUT                                         REPORT    22
000027           IF(ADVV .LE. GADV) GO TO 999                               REPORT    23
000031           GDAY=(T-TO)/24.                                            REPORT    24
000034           GEND=X-XOISCH                                              REPORT    25
000036           GBEG=OLDX-XOISCH                                           REPORT    26
000040           GADV=ADVV                                                  REPORT    27
000041       999 CONTINUE                                                   REPORT    28
000041           OLDX=X                                                     REPORT    29
000043           ROUT=ROUTIM                                                REPORT    30
000044           RETURN                                                     REPORT    31
000045           END                                                        REPORT    32
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
IMOVE
JMETH
XT
XOE
PC
JMOVE
IMETH
XE
PR
```

V. SUBROUTINE REPORR

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GOLETA FORTRAN I.3 * AUTO RFL * (07-12-72)                                            07/25/72

                SUBROUTINE RFPORR                                                REPORT    33
          C                                                                      REPORT    34
          C      PRINTING INTERIM PERFORMANCE PEPORT                             REPORT    35
          C                                                                      REPORT    36
000002          COMMON /ALL   / XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG                 ALL        2
               1,  AT,D,E,SK,T,DT,X,PR,XMAX,TMAX,DX,OV,TPRINT,OTPRNT,IMOVE,JMETH ALL        3
               2,  TSHFT,REPORT,OPPCT,TD,XD,XDISCH,ICHNG,XCHNG,TCHNG             ALL        4
000002          EQUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)                          ALL        5
000002          COMMON/MONEY/ JMMHH,DJM,DJMMH,OJMRD,OJMBMM,DMAINT,OJMBM,OJMGS    ALL        6
               1,  PMGS,JMCV,DJMFC,RDPLAN,HPLANT,GSPLAN                          ALL        7
               2,  ECPLAN,RDTIME,HTIME(2),GSTIME,ECTIME                          ALL        8
000002          COMMON/PERFRM/ RDUTIM,RDOTIM,UMHTIM,OMHTIM,GSUTIM,GSDTIM,ECUTIM  ALL        9
               1,  ECDTIM,GDAY,GADV,GENO,GBEG                                    ALL       10
000002          COMMON/LABOR/ RDMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2)   ALL       11
000002          REAL JMMHH,LD,LDB,LBIT,LBURN,LSTEEL,JMCV                         ALL       12
000002          DIMENSION G(8)                                                   ALL       13
000002          EQUIVALENCE (G,XT),(XE,XDE),(PR,PC)                              ALL       14
000002          OATA INIT,NEEDIN/2*0/                                            REPORT    38
000002          DIMENSION IVAL(20)                                               TEST       2
000002          COMMON/TEST/VALUE(30),NAME(30)                                   TEST       3
               1,IHEAD(110),JHEAD(100)                                           TEST       4
000002          EQUIVALENCE (IVAL,VALUE)                                         TEST       5
000002          DATA  IHEAD/7HINTERIM,7H PERFOR,7HMANCE R,7HEPORTS ,             REPORT    40
               17HDAYS SI,7HNCE COM,7HMENCED ,7HEXCAVAT,7HING    ,2*7H       ,   REPORT    41
               27HHEADING,7H POSITI,7HON(FEET,7H)       ,2*7H       ,            REPORT    42
               37HAVERAGE,7H ADVANC,7HE RATE(,7HFEET/OP,7HERATING,7H HOUR) ,     REPORT    43
               47HMAXIMUM,7H DAILY ,7HADVANCE,7HDAYS SI,7HNCE COM,7HMENCED ,     REPORT    44
               57HEXCAVAT,7HING    ,7H       ,4H    ,7HHEAOING,7H POSITI,        REPORT    45
               67HON-BEGI,7HNNING O,7HF THAT ,7HDAY(FEE,4HT)   ,7HHEADING,       REPORT    46
               77H POSITI,7HON-END ,7HOF THAT,7H DAY(FE,7HET)     ,4H    ,7HAVERAGE REPORT    47
               8,7H RATE F,7HOR THAT,7H DAY(FE,7HET/OPER,7HATING H,4HOUR),       REPORT    48
               97HCUMULAT,7HIVE SUB,7HSYSTEM ,7HPERFORM,6HANCE.,,7HELEMENT,      REPORT    49
               A7H/MEASUR,7HE      ,7H    OPE,7HRATIONA,7HL      ,7H      S,     REPORT    50
               B7HUBSYSTE,7HM      ,7HAVAILAB,7HILITY, ,7H       ,7H  UTILI,     REPORT    51
               C7HZATION,,2H, ,9*7H-------,2H--,7H,OPERAT,7HIONAL A,7HVAILABI,   REPORT    52
               D7HLITY=(T,7HOTAL SH,7HIFT TIM,7HE-DOWN ,7HTIME)/T,7HOTAL SH,     REPORT    53
               E7HIFT TIM,1HE,7H,,SUBSY,7HSTEM UT,7HILIZATI,7HON=(TOT,7HAL SHIF, REPORT    54
               F7HT TIME-,7HDOWN TI,7HME-IDLE,7H TIME)/,7HTOTAL S,7HHIFT TI,     REPORT    55
               G2HME/                                                            REPORT    56
000002          OATA  JHEAO/7HINTERIM,7H COST R,7HEPORT  ,7HOAYS SI,7HNCE COM,   REPORT    57
               17HMENCEO ,7HEXCAVAT,7HING    ,7H       ,3H   ,7HAVERAGE,7H COST P, REPORT  58
               2 7HER IN S,7HITU CUB,7HIC YARD,7H EXCAVA,3HTED,7HAVERAGE,        REPORT    59
               47H COST P,7HER FOOT,7H OF TUN,7HNEL    ,7H       ,3H   ,7HCUMULAT, REPORT  60
               57HIVE COS,7HT SUMMA,7HRY TO O,7HATE.,(O,7HOLLARS),7HELEMENT,     REPORT    61
               67H/CATEGO,7HRY     ,7HOIRECT ,7H     PL,7HANT ,  ,7H     JO,     REPORT    62
               67HB      ,7H   PERM,7HANENT  ,7H    OVE,7HR      ,7H ELEMEN,1HT, REPORT    63
               77HLABOR  ,                                                       REPORT    64
               7      7H    EQU,7HIPMENT ,7H    MAT,7HERIALS ,7H    MAT,         REPORT    65
               87HERIALS ,7H     HE,7HAO     ,7H  TOTAL,14*7H-------,3H---,      REPORT    66
               914*7H-------,3H---,                                              REPORT    67
               A7HGEOLOGY,7H CHANGE,4HO AT,5H DAYS,7H FEET F,7HROM POR,4HTAL.,   REPORT    68
               A7HNEW CHA,                                                       REPORT    69
               B7HRACTERI,7HSTICS A,7HRE.  UN,7HCONFINE,7HD COMPR,7HESSIVE ,     REPORT    70
               C7HSTRENGT,6HH(KSI)/                                              REPORT    71
          C                                                                      REPORT    72
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             C      INITIALIZATION
             C
000002           1 INIT=1
000003             IF(REPORT .EQ. 0.) REPORT=24.
000005             IF(TSHFT .EQ. 0.) TSHFT=24.
000007             IF(NEEDIN .EQ. 0) GO TO 999
000010             NEEDIN=0
000011             GO TO 3
             C
             C      NORMAL ENTRY
             C
000011             ENTRY REPORS
000016             IF(INIT .EQ. 1) GO TO 3
000020             NEEDIN =1
000021             GO TO 1
             C      COMPUTING DAY OF REPORT AND AVERAGE ADVANCE
000022           3 DAYS=(T-TO)/24.
000025             TSHFT=T-TO
000026             ADV=X-XOISCH
             C
             C      OPERATING TIME IS ASSUMED TO BE ROCK DISINTEGRATION UP TIME
000030             AVGADV=(X-XO)/RDUTIM
             C
             C      PRINTING INTERIM PERFORMANCE REPORTS
000033             PRINT 4
000036           4 FORMAT(1H1)
000036             PRINT 5,(IHEAD(I),I=1,10),DAYS,(IHEAD(I),I=12,17),ADV,(IHEAD(I),
                  1I=18,23),AVGADV
000072           5 FORMAT(////,46X,4A7,////,26X,6A7,F10.3,//,26X,6A7,F10.3,//,26X,
                  16A7,F10.3)
000072             PRINT 40,(IHEAD(I),I=24,33),GDAY,(IHEAD(I),I=34,40),GBEG,(IHEAD(I)
                  1,I=41,47),GEND,(IHEAD(I),I=48,54),GADV
000136          40 FORMAT(/,26X,3A7,//,34X,6A7,A4,F10.3,//,34X,6A7,A4,F10.3,//,34X,
                  16A7,A4,F10.3,//,34X,6A7,A4,F10.3)
000136             PRINT 80,(IHEAD(I),I=55,84)
000150          80 FORMAT(/,26X,4A7,A6,//,26X,9A7,//,51X,5A7,A2,//,26X,9A7,A21
000150             OPTIM=(TSHFT-RDDTIM)/TSHFT
000153             USETIM=RDUTIM/TSHFT
000154             PRINT 120,OPTIM,USETIM
000164         120 FORMAT(//,25X,19H ROCK FRAGMENTATION  ,F13.3,10X,F13.3)
000164             OPTIM=(TSHFT-DMHTIM)/TSHFT
000167             USETIM=UMHTIM/TSHFT
000170             PRINT 130,OPTIM,USETIM
000200         130 FORMAT(/,25X,19H MATERIALS HANDLING  ,F13.3,10X,F13.3)
000200             OPTIM=(TSHFT-GSDTIM)/TSHFT
000203             USETIM=GSUTIM/TSHFT
000204             PRINT 140,OPTIM,USETIM
000214         140 FORMAT(/  ,25X,19H GROUND SUPPORT     ,F13.3,10X,F13.31
000214             OPTIM=(TSHFT-ECDTIM)/TSHFT
000217             USETIM=ECUTIM/TSHFT
000220             PRINT 150,OPTIM,USETIM
000230         150 FORMAT(/,25X,22H ENVIRONMENTAL CONTROL  ,F10.3,10X,F13.3)
000230             PRINT 160,(IHEAD(I),I=85,107)
000242         160 FORMAT(//,25X,10A7,A1,///,24X,11A7,A2)
000242         999 CONTINUE
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000242        RETURN                                              REPORT   128
000243        END                                                 REPORT   129
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
IMOVE
JMETH
XT
XDE
PC
JMOVE
IMETH
XE
PR
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W.   SUBROUTINE REPORC

GOLETA FORTRAN I.3 • AUTO RFL • (07-12-72)   07/25/72

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                  SUBROUTINE REPORC                                                  REPORT   130
         C                                                                           REPORT   131
         C         PRINTING INTERIM COST REPORT                                      REPORT   132
         C                                                                           REPORT   133
000002            COMMON /ALL    / XT,STR,IA,RQO,CS,TAMB,FLOW,IFLAG                  ALL        2
                 1,  AT,D,E,SK,T,OT,X,PR,XMAX,TMAX,DX,OV,TPRINT,DTPRNT,IMOVE,JMETH   ALL        3
                 2,  TSHFT,REPORT,OPPCT,TO,XO,XOISCH,ICHNG,XCHNG,TCHNG               ALL        4
                  EQUIVALENCE (JMOVE,IMOVE),(IMETH,JMETH)                            ALL        5
000002            COMMON/MONEY/ JMMHM,OJM,DJMMH,DJMRD,OJMBMM,OMAINT,OJMBM,DJMGS      ALL        6
000002           1,  PHGS,JMCV,OJMEC,ROPLAN,HPLANT,GSPLAN                            ALL        7
                 2,  ECPLAN,RDTIME,HTIME(2),GSTIME,ECTIME                            ALL        8
000002            COMMON/PERFRM/ ROUTIM,ROOTIM,UMHTIM,OMHTIM,GSUTIM,GSDTIM,ECUTIM    ALL        9
                 1,  ECOTIM,GOAY,GADV,GENO,GBEG                                      ALL       10
000002            COMMON/LABOR/ ROMEN(10,2),HMEN(10,2,2),GSMEN(10,2),ECMEN(10,2)     ALL       11
000002            REAL JMMHM,LD,LOB,LBIT,LBURN,LSTEEL,JMCV                           ALL       12
000002            DIMENSION G(8)                                                     ALL       13
000002            EQUIVALENCE (G,XT),(XE,XDE),(PR,PC)                                ALL       14
000002            DIMENSION IVAL(20)                                                 TEST       2
000002            COMMON/TEST/VALUE(30),NAME(30)                                     TEST       3
                 1,IHEAD(100),JHEAD(100)                                             TEST       4
000002            EQUIVALENCE (IVAL,VALUE)                                           TEST       5
         C         INITIALIZATION                                                    REPORT   136
000002            DIMENSION ELEMEN(4,6),TOTAL(6)                                     REPORT   137
000002          1 INIT=1                                                             REPORT   138
000003            IF(OPPCT .EQ. 0.) OPPCT=.20                                        REPORT   139
000005            IF(REPORT .EQ. 0.) REPORT=4.                                       REPORT   140
000007            DO 2 I=1,2                                                         REPORT   141
000011            HTIME(I)=0                                                         REPORT   142
000012          2 CONTINUE                                                           REPORT   143
000014            GSTIME=0.                                                          REPORT   144
000015            RDTIME=0.                                                          REPORT   145
000016            ECTIME=0.                                                          REPORT   146
000017            IF(NEEDIN .EQ. 0) GO TO 999                                        REPORT   147
000020            NEEDIN=0                                                           REPORT   148
000020            GO TO 3                                                            REPORT   149
         C         NORMAL ENTRY                                                      REPORT   150
000021            ENTRY REPORO                                                       REPORT   151
000026            IF (INIT .EQ. 1) GO TO 3                                           REPORT   152
000030            NEEDIN=1                                                           REPORT   153
000031            GO TO 1                                                            REPORT   154
000032          3 DO 5 I=1,4                                                         REPORT   155
000034            DO 4 J=1,6                                                         REPORT   156
000035            ELEMEN(I,J)=0.                                                     REPORT   157
000040            TOTAL(J)=0.                                                        REPORT   158
000041          4 CONTINUE                                                           REPORT   159
000042          5 CONTINUE                                                           REPORT   160
         C                                                                           REPORT   161
         C         COMPUTE JOB MATERIAL ,PLANT AND EQUIPMENT COSTS FOR EACH PROCESS  REPORT   162
000044            ELEMEN(1,4)=0.                                                     REPORT   163
000045            ELEMEN(2,4)=0.                                                     REPORT   164
000046            ELEMEN(4,4)=0.                                                     REPORT   165
000047            ELEMEN(3,3)=0.                                                     REPORT   166
000050            ELEMEN(1,2)=ROPLAN                                                 REPORT   167
000051            ELEMEN(2,2)=HPLANT                                                 REPORT   168
000053            ELEMEN(3,2)=GSPLAN                                                 REPORT   169
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000054          ELEMEN(4,2)=ECPLAN                                          REPORT
000056          ELEMEN(1,3)=DJMRO+DJMRM                                     REPORT
000060          ELEMEN(2,3)=DJMHH                                           REPORT
000061          ELEMEN(3,4)=PMGS                                            REPORT
000063          ELEMEN(4,3)=DJMEC                                           REPORT
        C                                                                   REPORT
        C        COMPUTING LABOR COSTS FOR EACH GENERAL PROCESS             REPORT
        C                                                                   REPORT
000064          DO 6 I=1,10                                                 REPORT
000066          ELEMEN(1,1)=ELEMEN(1,1)+ROMEN(1,I)*ROMEN(I,2)*ROTIME        REPORT
000072          ELEMEN(3,1)=ELEMEN(3,1)+GSMEN(I,I)*GSMEN(I,2)*GSTIME        REPORT
000076          ELEMEN(4,1)=ELEMEN(4,1)+ECMEN(I,1)*ECMEN(I,2)*ECTIME        REPORT
000102        6 CONTINUE                                                    REPORT
000104          DO 70 J=1,2                                                 REPORT
000105          DO 7 I=1,10                                                 REPORT
000106          ELEMEN(2,1)=ELEMEN(2,1)+HMEN(I,1,J)*HMEN(I,2,J)*HTIME(J)    REPORT
000117        7 CONTINUE                                                    REPORT
000121       70 CONTINUE                                                    REPORT
000123          DO 9 I=1,4                                                  REPORT
000124          DO 8 J=1,4                                                  REPORT
000125          ELEMEN(I,5)=ELEMEN(I,5)+OPPCT*ELEMEN(I,J)                   REPORT
000133        8 CONTINUE                                                    REPORT
000135        9 CONTINUE                                                    REPORT
000137          DO 11 I=1,4                                                 REPORT
000140          DO 10 J=1,5                                                 REPORT
000141          ELEMEN(I,6)=ELEMEN(I,6)+ELEMEN(I,J)                         REPORT
000146       10 CONTINUE                                                    REPORT
000150       11 CONTINUE                                                    REPORT
000152          DO 13 I=1,4                                                 REPORT
000153          DO 12 J=1,6                                                 REPORT
000154          TOTAL(J)=TOTAL(J)+ELEMEN(I,J)                               REPORT
000162       12 CONTINUE                                                    REPORT
000163       13 CONTINUE                                                    REPORT
000165          DAYS=(T-TO)/24.                                             REPORT
000170          ACYARD=TOTAL(6)*108./(3.1415*(D**2)*(X-XO))                 REPORT
000176          ACFOOT=TOTAL(6)/(X-XO)                                      REPORT
000200          PRINT 14                                                    REPORT
000204       14 FORMAT(1H1)                                                 REPORT
000204          PRINT 15, (JHEAD(I),I=1,10),DAYS,(JHEAD(I),I=11,17),ACYARD, REPORT
               1(JHEAD(I),I=18,24),ACFOOT                                   REPORT
000240       15 FORMAT(///,49X,3A7,///8X,6A7,A3,F14.3,//,8X,6A7,A3,F13.2,//,8X, REPORT
               26A7,A3,F13.2)                                               REPORT
000240          PRINT 50,(JHEAD(I),I=25,69)                                 REPORT
000252       50 FORMAT(//,8X,6A7,//,8X,13A7,A1,/,29X,10A7,//,8X,14A7,A3)    REPORT
000252          PRINT 90,(ELEMEN(1,J),J=1,6)                                REPORT
000264       90 FORMAT(/  ,7X, 22H ROCK FRAGMENTATION    ,F9.2,F11.2,3X,F11.2,3X,F REPORT
               111.2,F10.2,F12.2)                                           REPORT
000264          PRINT 100,(ELEMEN(2,J),J=1,6)                               REPORT
000276      100 FORMAT(  /,7X,22H MATERIALS HANDLING     ,F9.2,F11.2,3X,F11.2, REPORT
               1 3X,F11.2,F10.2,F12.2)                                      REPORT
000276          PRINT 110,(ELEMEN(3,J),J=1,6)                               REPORT
000310      110 FORMAT(/  7X,22H GROUND SUPPORT          ,F9.2,F11.2,3X,F11.2,3X, REPORT
               1 F11.2,F10.2,F12.2)                                         REPORT
000310          PRINT 120,(ELEMEN(4,J),J=1,6)                               REPORT
000322      120 FORMAT(/  ,7X,22H ENVIRONMENTAL CONTROL    ,F9.2,F11.2,3X,F11.2,3X REPORT
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                  1,F11.2,F10.2,F12.2)                                               REPORT   225
000322             PRINT 130,(JHEAD(I),I=70,84)                                      REPORT   226
000334        130 FORMAT(/,8X,14A7,A3)                                               REPORT   227
000334             PRINT 140, (TOTAL(J),J=1,6)                                       REPORT   228
000346        140 FORMAT(//  7X,22H CATEGORY TOTAL          ,F9.2,F11.2,F14.2,F14.2, REPORT   229
                  1F10.2,F12.2)                                                      REPORT   230
000346             IF(ICHNG .EQ. 0) GO TO 999                                        REPORT   231
000347             ICHNG=0                                                           REPORT   232
000350             PRINT 150,(JHEAD(I),I=85,87),TCHNG,(JHEAD(I),I=88,88),XCHNG,      REPORT   233
                  1(JHEAD(I),I=89,100),STR                                           REPORT   234
000403        150 FORMAT(///,8X,2A7,A4,F10.3,A5,F10.3,2A7,A4,///,26X,8A7,A6,F12.4)   REPORT   235
000403             PRINT 165,IA                                                      REPORT   236
000411        165 FORMAT(51X,37H ABRASIVENESS                         ,I7)           REPORT   237
000411             PRINT 170,RQD                                                     REPORT   238
000417        170 FORMAT(51X,37H ROCK QUALITY DESIGNATION             ,F12.4)        REPORT   239
000417             PRINT 180,CS                                                      REPORT   240
000425        180 FORMAT(51X,37H IN SITU DENSITY(LBS/FT**3)           ,F12.4)        REPORT   241
000425             PRINT 190,TAMB                                                    REPORT   242
000433        190 FORMAT(51X,37H AMBIENT TEMPERATURE(DEG F)           ,F12.4)        REPORT   243
000433             PRINT 200,FLOW                                                    REPORT   244
000441        200 FORMAT(51X,37H WATER INFLOW(GAL/MIN)                ,F12.4)        REPORT   245
000441        999 CONTINUE                                                           REPORT   246
000441             RETURN                                                            REPORT   247
000442             END                                                               REPORT   248
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
IMOVE
JMETH
XT
XOE
PC
JMOVE
IMETH
XE
PR
```

X. SUBROUTINE HOLBRN (ICYCLE)

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                 SUBROUTINE HOLBRN(ICYCLE)
000003           COMMON/ALL/ XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG,AT,D,E,SK,T,DT,X,PR
                1,  XMAX,TMAX,TD,XD,XDISCH
                2,DX,DV
000003           COMMON/MONEY/ DJMRD
000003           COMMON/BLAST/ ADB,ADH,   CBIT,CBURN,CCAP,CEX,CM,CPL,CSTEEL,LBIT
                1,  LBURN,LD,LDB,LSTEEL,MEN,ND,NH,NHB,PF,POB,POD,TCHG,TIN,TOUT
                2,TYPEPF,WPL
000003           COMMON/OLOCDM/ JUMIN,JUMOUT,NCHRG,NDRILB,NDRILL
000003           COMMON/NEWCDM/LJUMIN,LJUMDT,LNCHRG,LNDRLB,LNDRIL
           C
           C     ELEMENT - ROCK DISINTEGRATION
           C     GENERAL PROCESS - DRILL AND BLAST
           C     ACTIVITY - DRILL HOLES OF BURN PATERN
           C     TECHNIQUE - PURCUSSION DRIFTSR AND BURN CUT DRILLS
           C
000003           DATA TIMED,TIMEB,PHI,SE,RD,TD,RDB,TDB /8*0./
000003           IF(ICYCLE .NE.  1 ) GO TO 50
000005           NDRILL=0
000005           NDRILB=0
000006           ICYCLE = 50
000007           IF (NH .NE. 0 .AND. NO .NE. 0 .AND. LD .NE. 0) GO TO 10
           C     OPTION 2
000017           PHI = 1.0
000020           NH = INT (( D +0.1*D*D)*PHI + .5)
000025           ND = INT (NH/8.0 + .5)
000030           IF (D.GT.15.) NHB =3
000034           IF (D.LE.15.) NHB =2
000037           NDB=1
000040           LD = DX + 1.0
000043           LDB=DX+1.0
000046        10 IF(STR .GT. 50.0) SE=60.
000052           IF (STR .LT. 50.0) SE=15.*EXP(0.031*STR)
000063           RD=1.98E3*POD/(ADH*SE)
           C     TIME TO DRILL HOLES
000066           TD = LD/RD * NH/ND
000073           RDB=1.98E3*POB/(ADB*SE)
000076           TDB=LDB/RDB * NHB/NDB
000103           TIMED=TD
000105           TIMEB=TDB
000107           PRINT 20,TD,TDB,NH
000120         ) FORMAT (* TIME TO DRILL HOLES - TD=*,F10.5,*   TDB=*,F10.5/
                *    * NO. OF HOLES =*,I10)
           C     KEEP TRACK OF TIME AND COSTS
000120        50 TIMED=TIMED-DT
000122           TIMEB=TIMEB-DT
000123           LNDRIL=0
000124           LNDRLB=0
000124           IF (TIMED.GT. 0.0) GO TO 60
000130           IF(NDRILL .EQ. 1) GO TO 57
000132           LNDRIL = 1
000132           IF (LBIT .LE.0.0 .OR.  LSTEEL .LE. 0.0) GO TO 55
000143           DJMRD= CBIT/LBIT * NH* LD + CSTEEL * LD * NH/LSTEEL +DJMRD
000154           GO TO 60
000154        55 DJMRD= .1*NH*LD + 0.25 * .1*NH*LD + DJMRD
000162           GO TO 60
000163        57 LNDRIL=1


000164        60 IF (TIMEB .GT. 0.0) RETURN
000166           IF(NDRILB .EQ. 1) GO TO 67
000170           LNDRLB=1
000171           IF (LBURN .LE. 0.0 .OR.  LSTEEL .LE. 0.0) GO TO 65
000201           DJMRD=CBURN/LBURN*NHB*LDB+CSTEEL*LDB*NHB/LSTEEL+DJMRD
000212           GO TO 70
000212        65 DJMRD=.25*.1*NHB*LDB+DJMRD
000217           GO TO 70
000217        67 LNDRLB=1
000220        70 RETURN
000221           END
```

Y. SUBROUTINE MOVEIN (ICYCLE)

```
                SUBROUTINE MOVEIN(ICYCLE)
          C
          C
          C     ELEMENT - ROCK FRAGMENTATION
          C     GENERAL PROCESS - DRILL AND BLAST
          C     ACTIVITY - REPOSITION AND ALIGN DRILLING EQUIPMENT
          C     TECHNIQUE - DRILL JUMBO (FULL FACE)
          C
000003          COMMON /GRND/ PSST(60,9)
000003          COMMON/ALL/ XT,STR,IA,RQD,CS,TAMB,FLOW,IFLAG,AT,D,E,SK,T,DT,X,PR
               1,  XMAX,TMAX,TO,XO,XDISCH
               2,DX,DV
000003          COMMON/MONEY/ DJMRD
000003          COMMON/BLAST/ ADB,ADH,   CBIT,CBURN,CCAP,CEX,CM,CPL,CSTEEL,LBIT
               1,  LBURN,LD,LDB,LSTEEL,MEN,ND,NH,NHB,PF,POB,POD,TCHG,TIN,TOUT
               2,TYPEPF,WPL
000003          COMMON/OLDCOM/ JUMIN,JUMOUT,NCHRG,NDRILB,NDRILL
000003          COMMON/NEWCOM/LJUMIN,LJUMOT,LNCHRG,LNDRLB,LNDRIL
000003          DATA TT/0./
000003          IF (ICYCLE .GT. 1)GO TO 10
000006          JUMIN=0
000006          ICYCLE = 50
000007          IF (TIN .LE. 0.0) TIN=.25
000012          TT=TIN
000013          DO 5 I=1,15
000015          IF(PSST(I,1) .LE. RQD) GO TO 6
000020        5 CONTINUE
000021        6 IF(PSST(I,3) .GT. 10.) GO TO 7
000025          DX=PSST(I,3)
000026          GO TO 8
000026        7 DX=10.
000030        8 DV=AT*DX
000032       10 TT=TT-DT
000034          LJUMIN=0
000035          IF(TT .LE. 0.0) LJUMIN=1
000037          RETURN
000040          END
```

Z. SUBROUTINE MOVOUT (ICYCLE)

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                SUBROUTINE MOVOUT (ICYCLE)
          C
          C     ELEMENT - ROCK FRAGMENTATION
          C     GENERAL PROCESS - DRILL AND BLAST
          C     ACTIVITY - MOVE OUT DRILLING EQUIPMENT AND BLAST
          C     TECHNIQUE - DRILL JUMBO (FULL FACE)
          C
000003          COMMON/ALL/ XT,STR,IA,RQD,CS,TAMB,FLOW,IFLAG,AT,D,E,SK,T,DT,X,PR
               1,  XMAX,TMAX,TO,XO,XDISCH
               2,DX,DV
000003          COMMON/MONEY/ DJMRD
000003          COMMON/BLAST/ ADB,ADH,   CBIT,CBURN,CCAP,CEX,CM,CPL,CSTEEL,LBIT
               1,  LBURN,LD,LDB,LSTEEL,MEN,ND,NH,NHB,PF,POB,POD,TCHG,TIN,TOUT
               2,TYPEPF,WPL
000003          COMMON/OLDCOM/ JUMIN,JUMOUT,NCHRG,NDRILB,NDRILL
000003          COMMON/NEWCOM/LJUMIN,LJUMOT,LNCHRG,LNDRLB,LNDRIL
000003          DATA TT/0./
000003          IF (ICYCLE .GT. 1) GO TO 10
000006          ICYCLE = 50
000006          JUMOUT=0
000007          IF (TOUT .LE. 0.0) TOUT=.25
          C     SET INITIAL CONDITIONS
000012          TT=TOUT
000013       10 TT=TT-DT
000015          LJUMOT=0
000015          IF(TT .LE. 0.0) LJUMOT=1
000020          RETURN
000021          END
```

AA. SUBROUTINE SETCHG (ICYCLE)

```
                SUBROUTINE SETCHG(ICYCLE)
000003          COMMON/ALL/ XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG,AT,D,F,SK,T,DT,X,PR
               1,   XMAX,TMAX,TO,XO,XDISCH
               2,DX,DV
000003          COMMON/MONEY/ DJMRD
000003          COMMON/BLAST/ ADB,ADH,    CBIT,CBURN,CCAP,CEX,CM,CPL,CSTEEL,LBIT
               1,   LBURN,LD,LDB,LSTEEL,MEN,ND,NH,NHB,PF,POB,POD,TCHG,TIN,TOUT
               2,TYPEPF,WPL
000003          COMMON/OLDCOM/ JUMIN,JUMOUT,NCHRG,NDRILB,NDRILL
000003          COMMON/NEWCOM/LJUMIN,LJUMOT,LNCHRG,LNDRLB,LNDRIL
          C
          C     ELEMENT - ROCK DISINTEGRATION
          C     GENERAL PROCESS - DRILL AND BLAST
          C     ACTIVITY - SET CHARGE
          C     TECHNIQUE = INDIVIDUAL HAND METHOD OR AUTOMATED
          C
000003          DATA CE,WEX,DTS,TT /4*0./
000003          IF (ICYCLE .NE. 1) GO TO 30
000005          ICYCLE = 50
000005          NCHRG=0
000006          IF (PF .NE. 0.0) GO TO 20
000007       10 IF(TYPEPF .NE. 3.) GO TO 15
000011          CE = 50.
000012          WPL=0.5
000014          CCAP=0.3
000015          CPL=0.2
000017          CEX = 0.06
000020          CM=1.
000022          GO TO 18
000023       15 CE = 70.
000024          WPL=0.
000025          CPL=0.
000026           CCAP = 0.3
000030           CEX = 0.3
000031          CM=1.
          C     COMPUTE POWDER REQUIRED
000033       18 PF=(27./144)*(ADH*CE/AT)*NH
000041       20 WEX = PF/27.0 * AT * DX
          C     COMPUTE TIME TO SET CHARGES
000044          IF (TCHG.LE. 0.0) TCHG = 4./60.
000047          IF(MEN .GT. 0) GO TO 21
000052          TMEN=NH/8.+.5
000055          MEN=INT(TMEN)
000056       21 DTS=TCHG*NH/MEN
000061          TT=DTS
000063          PRINT 25,PF,DTS
000073       30 TT=TT-DT
000075          LNCHRG=0
000075          IF(TT .GT. 0.0) RETURN
000100          LNCHRG = 1
000101          DJMRD=DJMRD+NH*(WPL*CPL)+NH*CCAP+WEX*CEX+DX*CM
000113       25 FORMAT (*  POWDER FACTOR=*,F10.5,5X,*TIME TO SET CHARGES=*,F10.5)
000113          RETURN
000113          END
```

BB. SUBROUTINE JETIMP

```
      SUBROUTINE JETIMP
C
C     ELEMENT - ROCK DISINTEGRATION
C     GENERAL PROCESS - WATER JET IMPACT. CONTINUOUS OR INTERMITTANT PULSES
C     ACTIVITY - JET IMPACT
C
      COMMON/ALL/ XT.STR.IA.ROD.CS.TAMB.FLOW.IFLAG.AT.D.F.SK.T.DT.X.PR
     1.  XMAX.TMAX.TO.XO.XDISCH
      COMMON/MONEY/ DJMPD
      COMMON/NJET / BLT.CPBRL.CSTPRJ.DJMWJM.DNOZZ.DTCJFT.DIMJET.DTRJET
     1.  ENERGJ.ETAGN.ETAJ.ETAIMP.ETAIPT.MODEJ.NGUNS.NJETS.PNOZZ.PPM
     2.  PRJPM.PULSED.TPBRL.VOLPRJ.VFLPRJ.VPRJ.XRJET.VFLJET
      COMMON/NEWCOM/ LNBARL.LMWJ.LMWJM.LMWJR.        EHEATJ.EQWATR.EDX
     1.  EDV
      COMMON/OLDCOM/ NBARL.MWJ.MWJM.MWJR.       HEATJ.QWATR.DX.DV
      EQUIVALENCE(SIGC.STR)
      EQUIVALENCE(WROCK.ROD)
      EQUIVALENCE (MPI.MWJ)
      EQUIVALENCE (LMPI.LMWJ)
      DATA PI /3.1415927/
      DATA INIT /0/
      DATA NEEDIN /0/
      DATA FACTA.FACTB.FACTC.XFACT.QFACT /5*0./
C                                INITIALIZE VARIABLES
   10 IF (PR .EQ. 0.) PR = 0.015
      IF (ETAJ .EQ. 0.) ETAJ = 0.3
      IF (ETAIMP .EQ. 0.) ETAIMP = 0.2
      IF (ENERGJ .NE. 0.) GO TO 100
      IF (MODEJ .EQ. 1) GO TO 70
C                                ENERGJ NOT INPUT. MODEJ = CONTINUOUS
      IF (SIGC .LT. 5.0 .OR. SIGC .GT. 25.0) GO TO 80
      ENERGJ = 47.0 * EXP (.09 * SIGC)
      GO TO 100
C                                ENERGJ NOT INPUT. MODEJ = INTERMITTENT
   70 IF (SIGC .LT. 15.0 .OR. SIGC .GT. 35.0) GO TO 80
      ENERGJ = 100. * EXP (.072 * SIGC)
      GO TO 100
   80 PRINT 85
   85 FORMAT (105HOJET ENERGY PER VOLUME OF ROCK BROKEN MUST BE SPECIFIE
     *D FOR THE ROCK STRENGTH ENCOUNTERED. RUN TERMINATED.   )
      CALL EXIT
C                                GENERATE FACTORS REQUIRED FOR CALCS
  100 XFACT = PI * D * D / 4.
      YFACT = PI * DNOZZ * DNOZZ / 4.
      ZFACT = PULSED * PPM / 60.
      XWRK = PNOZZ * 193.2 / 1.3
      VFLJET = SQRT (XWRK)
      QFACT = VFLJET * NJETS * YFACT * 25.
      POWREA = 0.0174 * DNOZZ * DNOZZ * PNOZZ ** 1.5
      IF (MODEJ .EQ. 0) GO TO 110
      QFACT = QFACT * ZFACT
      POWREA = POWREA * ZFACT
  110 CONTINUE
      TOTPWR = NJETS * POWREA
      PWRIN = TOTPWR / ETAJ
      FACTA = PWRIN * PR * 0.7452
      FACTB = (1. - ETAJ * ETAIMP) * PWRIN * 2545.2
      FACTC = 13.75 * TOTPWR / (XFACT * ENERGJ)
C                                IS CALL FOR INITIALIZATION ONLY
      INIT = 1
      IF (NEEDIN .EQ. 0) GO TO 999
      NEEDIN = 0
      GO TO 300
```

```
C                                  NORMAL ENTRY
C
C
      ENTRY JET
      IF (INIT .EQ. 1) GO TO 300
      NFEDIN = 1
      GO TO 10
  300 FHEATJ = 0.
      RDTIME=RDTIME+DT
      FDX = 0.
      FDV = 0.
      FOWATR = 0.
      IF(MWJ .GE. 1) GO TO 999
      DJMRD = DJMRD + (FACTA * DT)
      RDPLAN=RDPLAN+5.
      FHEATJ = FACTB * DT
      FDX = FACTC * DT
      FDV = XFACT * FDX
      FOWATR = QFACT * DT
  999 RETURN
      END
```

CC. SUBROUTINE JETAGN

```
      SUBROUTINE JETAGN
C
C     ELEMENT - ROCK DISINTEGRATION
C     GENERAL PROCESS - WATER JET
C     ACTIVITY - REPOSITION + ALIGN
C                               OR PROJECTILE FRAGMENTATION
      COMMON/ALL/ XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG,AT,D,F,SK,T,DT,X,PR
     1,  XMAX,TMAX,TO,XO,XDISCH
      COMMON/MONEY/ DJMRD
      COMMON/NJET / PLT,CPBPL,CSTPRJ,DJMWJM,DNOZZ,DTCJET,DTMJET,DTRJET
     1,  ENERGJ,FTAGN,ETAJ,FTAIMP,FTAIPT,NODEJ,NGUNS,NJETS,PNOZZ,PPM
     2,  PRJPM,PULSED,TRBRL,VOLPRJ,VFLPRJ,WPRJ,XRJET,VFLJET
      COMMON/NEWCOM/ LNBARL,LMWJ,LMWJM,LMWJR,      FHEATJ,FQWATR,FDX
     1,  FDV
      COMMON/OLDCOM/ NBARL,MWJ,MWJM,MWJR,      HEATJ,QWATR,DX,DV
      EQUIVALENCE(SIGC,STR)
      EQUIVALENCE(WROCK,ROD)
      EQUIVALENCE (MPI,MWJ)
      EQUIVALENCE (LMPI,LMWJ)
      DATA DISTJ /0./
      DATA ELPSD /0./
      DATA OLDPOS /0./
      DATA INIT /0/
      DATA NEEDIN /0/
      ENTRY PRJAGN
C                               INITIALIZE
   10 MWJR=1
      IF (DTRJET .EQ. 0.) DTRJET = 0.25
      OLDPOS=X
      INIT = 1
      IF (NEEDIN .EQ. 0) GO TO 999
      NEEDIN = 0
      GO TO 50
C                               NORMAL ENTRIES
      ENTRY JETPOS
      ENTRY PRJPOS
      IF (INIT .EQ. 1) GO TO 50
      NEEDIN = 1
      GO TO 10
   50 IF (MWJ .EQ. 0) GO TO 100
C                               WATER JET (OR PROJECTILE GUN) STOPPED
      IF (MWJR .EQ. 1) GO TO 999
C                               REPOSITIONING NOT YET COMPLETED
      ELPSD = ELPSD + DT
      IF (ELPSD .LT. DTRJET) GO TO 999
      LMWJR = 1
      LMWJ = LMWJ - 1
      OLDPOS = X
      ELPSD = 0.
      GO TO 999
C                               WATER JET (OR PROJECTILE GUN) IS OPERATING
  100 DISTJ = X - OLDPOS + FDX
C        NOTE ***  FOR A GIVEN CYCLE, FDX MUST BE CALCULATED BEFORE THIS
C          STATEMENT IS EXECUTED, SINCE, TO BE CONSISTENT WITH OTHER
C          LOGIC, DISTJ MUST REFLECT THE DISTANCE AT THE END OF THE
C          CURRENT CYCLE. HENCE, JET OR PRJIMP MUST BE CALLED BEFORE
C          CALLING JETPOS OR PRJPOS.




      IF (DISTJ .LT. XRJET) GO TO 999
      LMWJ = LMWJ + 1
      LMWJR = 0
  999 RETURN
      END
```

DD. SUBROUTINE JETMNT

```
      SUBROUTINE JETMNT
C
C     ELEMENT - ROCK DISINTEGRATION
C      GENERL PROCESS-WATER JET AND PROJECTILE
C     ACTIVITY - GENERAL MAINTENANCE + REPAIR
C
      COMMON/ALL/ XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG,AT,D,E,SK,T,DT,X,PR
     1,  XMAX,TMAX,TO,XO,XOISCH
      COMMON/MONEY/ DJMRD
      COMMON/NJET / BLT,CPBRL,CSTPRJ,DJMWJM,DNOZZ,DTCJET,DTMJET,DTRJET
     1,  ENERGJ,ETAGN,ETAJ,ETAIMP,ETAIPT,MODEJ,NGUNS,NJETS,PNOZZ,PPM
     2,  PRJPM,PULSED,TRBPL,VOLPRJ,VELPRJ,WPRJ,XRJET,VELJET
      COMMON/NEWCOM/ LNBARL,LMWJ,LMWJM,LMWJR,      FHEATJ,FQWATR,FDX
     1,  FDV
      COMMON/OLDCOM/ NBARL,MWJ,MWJM,MWJR,      HEATJ,QWATR,DX,DV
      EQUIVALENCE(SIGC,STR)
      EQUIVALENCE(WROCK,ROD)
      EQUIVALENCE (MPI,MWJ)
      EQUIVALENCE (LMPI,LMWJ)
      DATA INIT /0/
      DATA NEEDIN /0/
      DATA IPRJ /0/
C                                 INITIALIZATION
   10 IF (DTCJET .EQ. 0.) DTCJET = 6.
      IF (DTMJET .EQ. 0.) DTMJET = 2.
      IF (IPRJ .EQ. 1 .AND. DJMWJM.EQ.0.) DJMWJM = 200.
      IPRJ = 0
      TMNT = 0.
      TIMBT = DTCJET
      MWJ=0
      MWJM=1
      INIT = 1
      IF (NEEDIN .EQ. 0) GO TO 999
      NEEDIN = 0
      GO TO 200
      ENTRY PRJMNT
      IPRJ = 1
      GO TO 10
C                                 NORMAL ENTRIES
      ENTRY PRJRPR
      IPRJ = 1
      ENTRY JETRPR
      IF (INIT .EQ. 1) GO TO 200
      NEEDIN = 1
      GO TO 10
C                                 IS MAINTENANCE IN PROGRESS
  200 IF (MWJM .EQ. 0) GO TO 400
C                                 IS MAINTENANCE REQUIRED
      TIMBT = TIMBT - DT
      IF (TIMBT .GT. 0.) GO TO 999
C                                 IS REPOSITIONING IN PROGRESS
      IF (MWJR .EQ. 0) GO TO 999
      LMWJM = 0
      LMWJ = LMWJ + 1
      GO TO 999
C                                 UPDATE PROGRESS OF MAINTENANCE
  400 TMNT = TMNT + DT
C                                 IS IT COMPLETED
      IF (TMNT .LT. DTMJET) GO TO 999
      LMWJM = 1
      LMWJ = LMWJ - 1
C        NOTE ** TO FORCE REPOSITIONING AFTER COMPLETION OF MAINTENANCE.
C          REPLACE STATEMENT #LMWJ = LMWJ-1# WITH #LMWJR=0# .
      DJMRD = DJMWJM + DJMRD
      TIMBT = DTCJET
      TMNT = 0.
  999 RETURN
      END
```

EE. SUBROUTINE PROJTL

```
      SUBROUTINE PROJTL
C
C     ELEMENT - ROCK DISINTEGRATION
C     GENERAL PROCESS - PROJECTILE FRAGMENTATION
C     ACTIVITY - PROJECTILE IMPACT
C                         OR PROJECTILE FRAGMENTATION
C
      COMMON/ALL/ XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG,AT,D,E,SK,T,DT,X,PR
     1,  XMAX,TMAX,TO,XO,XDISCH
      COMMON/MONEY/ DJMRD
      COMMON/NJET / PLT,CPBRL,CSTPRJ,DJMWJM,DNOZZ,DTCJET,DTMJET,DTPJET
     1,  ENERGJ,ETAGN,ETAJ,ETAIMP,ETAIPT,MODEJ,NGUNS,NJETS,PNOZZ,PPM
     2,  PRJPM,PULSED,TRBRL,VOLPRJ,VELPRJ,WPRJ,XRJET
      COMMON/NEWCOM/ LNBARL,LMWJ,LMWJM,LMWJR,       FHEATJ,FQWATR,FDX
     1,  FDV
      COMMON/OLDCOM/ NBARL,MWJ,MWJM,MWJR,       HEATJ,QWATR,DX,DV
      EQUIVALENCE(WROCK,CS)
      EQUIVALENCE(SIGC,STR)
      EQUIVALENCE (MPI,MWJ)
      EQUIVALENCE (LMPI,LMWJ)
      DATA INIT /0/
      DATA NEEDIN /0/
      DATA FACTA,FACTB,FACTC,FACTD,FACTE /5*0./
C                               INITIALIZE
   10 IF (ETAGN .EQ. 0.) ETAGN = 0.3
      IF (ETAIPT .EQ. 0.) ETAIPT = 0.2
C                               PROJECTILE ENERGY
C                               IS CALL FOR INITIALIZATION ONLY
      INIT = 1
      IF (NEEDIN .EQ. 0) GO TO 999
      NEEDIN = 0
      GO TO 200
C                               NORMAL ENTRY
      ENTRY PRJIMP
      IF (INIT .EQ. 1) GO TO 200
      NEEDIN = 1
      GO TO 10
  200 EPFT = WPRJ * VELPRJ * VELPRJ / 64.4
C                               PROJECTILE DENSITY
      RHOP=1728.*WPRJ/VOLPRJ
C                               ROCK DENSITY
      RHOR=WROCK
C                               ROCK FRAGMENTED PER PROJECTILE
      XWRK = RHOP / RHOR
      RMASS=1.63E-5*(SQRT(XWRK)*EPFT)**1.189
      RVOLFT=RMASS/WROCK
C                               CONSTRUCT FACTORS USED FOR EACH TIME INCREMENT
      IF(IFST .EQ. 1) GO TO 11
      IFST=1
      PRINT 111,EPFT,RHOP,RHOR
  111 FORMAT(1X, 5HEPFT=,E14.4,6H RHOP=,E14.4,6H RHOR=,E14.4)
      PRINT 112,XWRK,RMASS,RVOLFT
  112 FORMAT(1X, 6H XWRK=,E14.4,7H RMASS=,E14.4,8H RVOLFT=,E14.4)
C                               END OF DEBUG
   11 XWRK = PRJPM * 60.
      FACTA = RVOLFT * NGUNS * XWRK
      FACTB = 3.1415927 * D * D / 4.
```

```
      FACTC = EPFT * NGUNS * XWRK * 3.766E-7 / ETAGN
      FACTD = CSTPRJ * XWRK
      FACTE = 3413.0 * (1 - ETAGN * ETAIPT)
      FDV=0.
      FDX = 0.
      FHEATJ=0.
      IF (MPI .GE. 1) GO TO 999
C                                   ROCK FRAGMENTED DURING DELTA-T
      FDV = FACTA * DT
      FOX = FDV / FACTB
C                                   POWER COSTS
      TOTKWH = FACTC * DT
      PCST = TOTKWH * PR
C                                   PROJECTILE COSTS
      PJCST = FACTD * DT
C                                   TOTAL COST
      DJMRD = DJMRD + PCST + PJCST
      FHEATJ=TOTKWH*FACTE
  999 RETURN
      END
```

FF. SUBROUTINE PRJBR

```
      SUBROUTINE PRJBR
C
C     ELEMENT - ROCK DISINTEGRATION
C     GENERAL PROCESS - PROJECTILE FRAGMENTATION
C     ACTIVITY - BARREL REPLACEMENT
C
      COMMON/ALL/ XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG,AT,D,F,SK,T,DT,X,PR
     1,  XMAX,TMAX,TO,XO,XDISCH
      COMMON/MONEY/ D,MED
      COMMON/NJET / BLT,CBRRL,CSTPRJ,DJMWJM,DNOZZ,DICJET,DIMJET,DTWJET
     1,  ENERGJ,ETIGN,ETAJ,ETAIMP,ETAIPT,MODEJ,NGUNS,NJETS,PNOZZ,PPM
     2,  PRJPM,PULSED,TBRRL,VOLPRJ,VELPRJ,WPRJ,XRJET
      COMMON/NEWCOM/ LNBARL,LMWJ,LMWJM,LMWJR,       FHEATJ,FDWATR,FDX
     1,  FDV
      COMMON/OLDCOM/ NBARL,MWJ,MWJM,MWJR,      HEATJ,DWATR,DX,DV
      EQUIVALENCE(SIGC,STR)
      EQUIVALENCE(NROCK,CS)
      EQUIVALENCE (MPI,MWJ)
      EQUIVALENCE (LMPI,LMWJ)
      DATA TBR /0./
      DATA OPTIM /0./
      DATA INIT /0/
      DATA NEEDIN /0/
      DATA TT,CFACT /2*0./
C                             INITIALIZE
   10 TT = TBRRL * NGUNS
      NBARL=1
      CFACT = CBRRL * NGUNS
      INIT = 1
      IF (NEEDIN .EQ. 0) GO TO 999
      NEEDIN = 0
      GO TO 200
C                             NORMAL ENTRY
      ENTRY PRJBRL
      IF (INIT .EQ. 1) GO TO 200
      NEEDIN = 1
      GO TO 10
C                             IS BARREL REPLACEMENT IN PROGRESS
  200 IF (NBARL .EQ. 0) GO TO 400
C                             REPLACEMENT NOT IN PROGRESS. IS IT REQUIRED
      OPTIM = OPTIM + DT
      IF (OPTIM .LT. BLT) GO TO 999
C                             IS REPOSITIONING IN PROGRESS
      IF (MWJR .EQ. 0) GO TO 999
      LNBARL = 0
      LMPI = LMPI + 1
      GO TO 999
C                             REPLACEMENT IN PROGRESS. UPDATE PROGRESS
  400 TBR = TBR + DT
      IF (TBR .LT. TT) GO TO 999
C                             REPLACEMENT COMPLETED
      LNBARL = 1
      LMPI = LMPI - 1
      DJMRD = DJMRD + CFACT
      TBR = 0.
      OPTIM = 0.
  999 RETURN
      END
```

GG. SUBROUTINE MUKLOD

```
      SUBROUTINE MUKLOD
C
C     ELEMENT - MATERIALS HANDLING
C     GENERAL PROCESS - MACHINE LOADERS + SHOVELS
C     ACTIVITY - LOADING MUCK AT FACE
C
      COMMON/ALL/ XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG,AT,D,E,SK,T,DT,X,PR
     1,  XMAX,TMAX,TO,XO,XDISCH
      COMMON/WHEELS/ NCARS,MLTYP,QUC,WUC
      COMMON/CONVEY/ ACM,OTBS,DWM,FF,FL,HP,OC,SMIN,WBI,
     1   WP,XLF,NSURGE,QE,QP,SM,DTCB,DTMB,AB,VBI,NEXON,NGEO,XE,LNSURG,
     2   STIME,ODMR,DTMI,DTMO,FLM
      COMMON/NEWCOM/ LMACON,LMCAPC,LNSPLC,LLOADR,FOL,LMKIN,LMUKDT,LNBYHY
     1,LTSTAT(25,4),LKSTOP(25),LLVHCL,FDV
      COMMON/OLDCOM/ MACON,MCAPC,NSPLIC,LOADR,QL,MKIN,MUKOT,NBYBY
     1,TTSTAT(25,4),KSTOP(25),LVEHCL,DV
      EQUIVALENCE(LLODR,LLOADR)
      DATA TIMEL,DX,QUF,WUF,CSPERK /5*0./
      DATA NCRS,INIT,NEEDIN /3*0/
C                               INITIALIZATION
  100 IF (ODMR .EQ. 0.) ODMR = 5400.
      IF (STIME .EQ. 0.) STIME = .05
      CSPERK = CS / (SK * 2000.)
      INIT = 1
      IF (NEEDIN .EQ. 0) GO TO 900
      NEEDIN = 0
      GO TO 120
C                               NORMAL ENTRY
      ENTRY LODMUK
      IF (INIT.EQ. 1) GO TO 120
      NEEDIN = 1
      GO TO 100
  120 IF (MLTYP .EQ. 2) GO TO 500
C                               UNITIZED MAIN LINE SYSTEM
      IF (LVEHCL .EQ. 0) GO TO 900
C                               A UNIT IS AVAILABLE FOR LOADING
      FDV=DV
      LLODR = 0
      IF (TIMEL .GT. 0.) GO TO 300
      DQ = ODMR * DT
  130 XWRK=FDV*SK
      IF (XWRK - DQ .GE. 0.) GO TO 150
      DQ = XWRK
      LLODR = 1
      FDV=0.
      GO TO 160
  150 FDV=FDV-(DQ/SK)
C                               VOL + WEIGHT CAP OF UNIT NOW BEING FILLED
  160 QUF = QUF + DQ
      WUF = WUF + (DQ * CSPERK)
      IF (QUC .GT. QUF .AND. WUC .GT. WUF) GO TO 900
C                               UNIT IS FILLED + CAN BE RELEASED
      XWRK = QUF - QUC
      FDV=FDV+XWRK/SK
      QUF=0.
      WUF=0.
      TIMEL = XWRK / ODMR
```

```
      GO TO 320
C                                 UNITS ARE BEING SWITCHED
  300 TIMEL = TIMEL + DT
  320 IF (TIMEL .LT. STIME) GO TO 900
      DQ = QDMR * (TIMEL - STIME)
      TIMEL = 0.
      IF (NCARS .EQ. 0) GO TO 350
      NCRS = NCRS + 1
      IF(NCRS .LE. NCARS) GO TO 130
C                                 RELEASE VEHICLE
      NCRS = 0
  350 I = LVEHCL
      LTSTAT(I,1)=7
      LKSTOP(I)=5
      QUF = 0.
      WUF = 0.
      GO TO 130
C                                 CONTINUOUS MAIN LINE SYSTEM
  500 DQ = QDMR * DT
      NCRS=0
      LLOOP = 0
      XWRK = DV * SK
      IF (XWRK - DQ .GE. 0.) GO TO 550
      DQ = XWRK
      LLOOP = 1
      FDV=0.
      GO TO 600
  550 FDV=DV-DQ/SK
  600 FQL=DQ/DT
  900 QUFF=QUF/1.7
      PRINT 399,NCRS,QUFF,WUF
  399 FORMAT(66X,I7,2F10.2)
      RETURN
      END
```

HH. SUBROUTINE MUKIN

```
      SUBROUTINE MUKIN
C
C     ELEMENT - MATERIALS HANDLING
C     GENERAL PROCESS - MACHINE LOADERS + SHOVELS
C     ACTIVITY - MOVE MUCKERS TO MUCK PILE
C
C     ***CURRENTLY, THE CONTROL PROGRAM MUST SET  MKIN TO 0  TO
C            INITIATE MOVING IN.
      COMMON/ALL/ XT,STP,IA,ROD,CS,TAMB,FLOW,IFLAG,AT,D,F,SK,T,DT,X,PR
     1,  XMAX,TMAX,TO,XO,XDISCH
      COMMON/WHEELS/ NCARS,MLTYP,QUC,WUC
      COMMON/CONVEY/ ACM,DIBS,DWM,FE,FL,HP,OC,SMIN,WBI,
     1   WP,XLF,NSURGE,QE,OP,SM,DTCB,DTMB,AB,VBI,NFXGN,NGFO,XF,LNSURG,
     2   STIME,ODMR,DTMI,DTMO,FLM
      COMMON/NEWCOM/ LMACON,LMCAPC,LNSPLC,LLOADR,FOL,LMKIN,LMUKOT,LNBYBY
     1,LTSTAT(25,4),LKSTOP(25),LLVHCL,FDV
      COMMON/OLDCOM/ MACON,MCAPC,NSPLIC,LOADR,QL,MKIN,MUKOT,NBYBY
     1,ITSTAT(25,4),KSTOP(25),LVEHCL,DV
      EQUIVALENCE(LLODR,LLOADR)
      DATA INIT,NEEDIN /2*0/
      DATA TIMIN /0./
C                               INITIALIZATION
  100 IF (DTMI .EQ. 0.) DTMI = 1./12.
      TIMIN = DTMI
      INIT = 1
      IF (NEEDIN .EQ. 0) GO TO 900
      NEEDIN = 0
      GO TO 200
C                               NORMAL ENTRY
      ENTRY INMUK
      IF (INIT .EQ. 1) GO TO 200
      NEEDIN = 1
      GO TO 100
  200 IF (MKIN .NE. 0) GO TO 900
C                               MUCKERS BEING MOVED TO MUCKPILE
      TIMIN = TIMIN - DT
      IF (TIMIN .GT. 0.) GO TO 900
      LMKIN = 1
      TIMIN = DTMI
  900 RETURN
      END
```

II. SUBROUTINE MUKOUT

```
      SUBROUTINE MUKOUT
C
C     ELEMENT - MATERIALS HANDLING
C     GENERAL PROCESS - MACHINE LOADERS + SHOVELS
C     ACTIVITY - MOVE MUCKERS AWAY FROM FACE
C
C     ***CURRENTLY, THE CONTROL PROGRAM MUST SET MUKOT  TO 0 TO
C             INITIATE MOVING OUT.
      COMMON/ALL/ XI,STR,IA,ROD,CS,TAMB,FLOW,IFLAG,AT,O,E,SK,T,DT,X,PR
     1,  XMAX,TMSK,TO,IO,XDISCH
      COMMON/WHEELS/ NCARS,MLTYP,DUC,WUC
      COMMON/CONVEY/ ACM,DIPS,DWM,EE,FL,HP,OC,SHIN,WRI,
     I   WP,XLF,NSURGE,DE,DP,SM,DTCR,DTMR,AR,VRI,NEXON,NCEO,XF,LNSURG,
     2   STIME,COMR,DTMI,DTMO,FLM
      COMMON/NEWCOM/ LMACON,LMCAPC,LNSPLC,LLOADR,FCL,LMKIN,LMUKOT,LNRYRY
     1,LTSTAT(25,4),LKSTOP(25),LLVHCL,FDV
      COMMON/OLOCOM/ MACON,MCAPC,NSPLIC,LOADR,OL,MKIN,MUKOT,NRYRY
     1,ITSTAT(25,4),KSTOP(25),LVEHCL,DV
      EQUIVALENCE(LLOOR,LLOADR)
      DATA INIT,NEEDIN /2*0/
      DATA TIM /0./
C                                INITIALIZE
  100 IF (DTMO .EQ. 0.) DTMO = 1./12.
      TIM = DTMO
      INIT = 1
      IF (NEEDIN .EQ. 0) GO TO 900
      NEEDIN = 0
      GO TO 200
C                                NORMAL ENTRY
      ENTRY OUTMUK
      IF (INIT .EQ. 1) GO TO 200
      NEEDIN = 1
      GO TO 100
  200 IF (MUKOT .NE. 0) GO TO 900
      TIM = TIM - DT
      IF (TIM .GT. 0.) GO TO 900
      LMUKOT = 1
      TIM = DTMO
  900 RETURN
      END
```

JJ. SUBROUTINE TRUKHL

```
      SUBROUTINE TRUKHL
C
C          ELEMENT - MATERIALS HANDLING
C          GENERAL PROCESS - TRUCK SYSTEM
C          ACTIVITY - LONG HAUL MUCK TRANSPORT
C          TECHNIQUE - RUBBER-TIRED INDIVIDUAL DIESEL POWER TRUCK UNITS
C                      DUAL ROADWAY)
C
      COMMON/ALL/ XT,STP,IA,ROD,CS,TAMB,FLOW,IFLAG,AT,D,F,SK,T,DT,X,PR
     1,  XMAX,TMAX,TO,XO,KDISCH,DX,DV
      COMMON/WHEELS/ AE,AF,AMAX,AMINL,BSL,CARCAP,CP,DF,OF,DTAS,DTMA,DTV
     1,  EL,FC,FR,FT,HPA,HPFA,HPEV,HPFV,HPV,ISW(25),LOCO,MC,ML,MLTYP
     2,  NCARS,NPOINT,NTD,NTINIT,NTM,NTMAX,NUMLD,XP,NTMILP,NTMLPP,NTRACK
     3,  QUC,SL,STATUS(30),TCURVX(20),TCURVY(20),TMAINT,TWF,VD,VS,VE,VF
     4,  VMAX,WC,WL,WHY(24),WHR,WUC,XDS,AMAXL
      COMMON/CONVEY/ AB,ACM,DMAINT,DTCH,DTHS,DTMB,DTMI,DTMO,DWW,EF,FL
     1,  HP,LNSURG,NEXOU,NGEO,NSURGE,OC,OE,OOMR,OP,SM,SMIN,STIME,VBI
     2,  WBI,WP,XE,XLF
      COMMON/NEWCOM/ LIFILO,LKSTOP(25),LKUNLD,LLSTOP,LLVHCL,LNRYRY
     1,LNSWCH,LNTROA,LNVHCL,LNMSWT,FSWTCH(20),FTFC(25),FTOP(25)
     3,  FTSTAT(25,4),FUTIME(25),LLOADR
      COMMON/OLDCOM/ IFILD,KSTOP(25),KUNLO,LSTOP,LVEHCL,NRYRY,NSWCH
     1,  NTROA,NVEHCL,NUMSWT,SWITCH(20),TFC(25),TOP(25),TSTAT(25,4)
     2,  UTIME(25),LOADR
      DIMENSION LTSTAT(25,4),ITSTAT(25,4)
      EQUIVALENCE (COMOLD,IFILD),(COMNEW,LIFILO),(NVEHCL,NTRAIN,NTRUCK)
     1, (LVEHCL,LTRAIN,LTRUCK),                        (NTDA,NTROA),
     2   (FTSTAT,LTSTAT),(TSTAT,ITSTAT)
     3,(LLVHCL,LLTRAN,LLTRUK),(LNVHCL,LNTRAN,LNTRUK)
      DIMENSION STATE(25,4)
      DIMENSION ISTATE(25,4)
      EQUIVALENCE (STATE,ISTATE)
      DATA STATE /100*0./
      DIMENSION JSTOP(25)
      DATA JSTOP /25*0/
      DIMENSION TEMS(25)
      DIMENSION TEMT(25)
      DATA INITSW, IRETSW /2*0/
      DATA IOPTN /1/
      EQUIVALENCE (TWE,WE)
      DATA TEMS /25*0./
      DATA TEMT /25*0./
      DATA AEMAX,TLIM,TLIMF,WECI,WFC2,WEFACI,WEFAC2,HPEVP /8*0./
      DATA HPFAC,HPAFAC,HPVFAC,WEFAC,FRFAC,FRWE,AEMAX /7*0./
      DATA HPFVP,HPEAH,HPFAH,DINCP,CPFC,VEFT,VFFT,VDSO,DELMAX /9*0./
C
C                            PARAMETER INITIALIZATION
C
  100 INITSW = 1
      IF (NTRUCK .EQ. 0) NTRUCK = 1
      ITSTAT(I,I) = 2
      TSTAT(I,2) = 0.
      TSTAT(I,3) = 0.
      TSTAT(I,4) = 0.
      DO 120 I=1,25
      ISW(I) = 0
      TEMT(I) = 0.
      TEMS(I) = 0.
  120 CONTINUE
      IF (WE .EQ. 0.) GO TO 200
C                            OPTION 2
      IOPTN = 2
      IF (FR .EQ. 0.) FR = 65.
      IF (EL .EQ. 0.) EL = 0.85
      IF (FT .EQ. 0.) FT = 0.36
      IF (AF .EQ. 0.) AE = 99999.
      IF (AF .EQ. 0.) AF = AE
      HPFAC = EL * 375.
      HPAFAC = HPFAC * HPA
      HPVFAC = HPFAC * HPV
```

```
      WEFAC = WE * (1.35 * CARCAP)
      FRFAC = FR * WEFAC
      FRWE = FR * WE
      AEMAX = AF
      AFMAX = AF
      XWRK = FT * 2000.
      TLIM = XWRK * WE
      TLIMF = XWRK * WEFAC
      WEC1 = WE / 39.4
      WEC2 = 39.4 / WE
      WEFAC1 = 39.4 / WEFAC
      WEFAC2 = WEFAC / 39.4
      XWRK = HPVFAC / FRWF
      IF (VE * (VF - XWRK) .GE. 0.)VF = XWRK
      XWRK = HPVFAC / FRFAC
      IF (VF * (VF - XWRK) .GE. 0.) VF = XWRK
      HPEVP = FRWE * VF / HPFAC
      HPFVP = FRFAC * VF / HPFAC
      GO TO 250
C                                 OPTION 1
  200 CONTINUE
      HPFAH = HPFA
      HPFAH = HPFA
C                                 BOTH OPTIONS
  250 DINCR = 50.
      IF (IOPTN .EQ. 2) GO TO 255
      XWRK = 2640. * VF * VF / DE
      IF (XWRK .LT. DINCR) DINCR = XWRK
      XWRK = 2640. * (VF * VF - VD * VD) / DF
      IF (XWRK .LT. DINCR) DINCR = XWRK
  255 DELMAX = DINCR / (5280. * VE)
      IF (CP .EQ. 0.) CP = 0.14
      IF (FC .EQ. 0.) FC = 0.06
      CPFC = CP * FC
      VEFT = VF * 5280.
      VFFT = VF * 5280.
      VDSQ = VD * VD
      PRINT 260, VF, VF
  260 FORMAT (12H0TRUCK VF = ,F10.3,5H VF =, F10.3)
C                                 WAS CALL FOR INITIALIZATION ONLY
      IF (IRETSW) 270,999,270
  270 IRETSW = 0
      GO TO 350
C
C                                 NORMAL ENTRY
C
      ENTRY TRUKTR
C                                 HAS INITIALIZATION BEEN PERFORMED
      IF (INITSW) 350,320,350
  320 IRETSW = 1
      GO TO 100
  350 XWRK = (DT / DELMAX) + 1
      NITER = XWRK
      YWRK = NITER
      TFRAC = XWRK - YWRK
C                                 RETRIEVE /OLDWRK/ VARIABLES
      DO 355 J= 1,NTRUCK
      STATE(J,1)=TSTAT(J,1)
      STATE(J,2) = TSTAT(J,2)
      STATE(J,3) = TSTAT(J,3)
      STATE(J,4) = TSTAT(J,4)
      JSTOP(J) = KSTOP(J)
  355 CONTINUE
      ISTOPT = LSTOP
  360 LLTRUK = 0
      DELTAT = DELMAX
      IF (NITER .EQ. 1) DELTAT = TFRAC * DELMAX
      DT2640 = DELTAT * 2640.
      DTVEFT = DELTAT * VEFT
```

```
      DTVFFT = DELTAT * VFFT
      DTCPFC = DELTAT * CPFC
      OTDAYS = DELTAT / 24.
      IWRK = ISTOPT + I
      GO TO (500,400,450),IWRK
C                                SYSTEM MUST BE SHUT DOWN
  400 DO 420 J=I,NTRUCK
      IF (JSTOP(J) .NE. 0) GO TO 420
      IWRK = ISTATE(J,1)
      IF ((IWRK-I0) * (IWRK-II) .EQ. 0) GO TO 420
      JSTOP(J) = 4
      IF ((IWRK - 6)*(IWRK-7) .EQ. 0) GO TO 420
      JWRK = (IWRK + 1) / 2
      IWRK = IWRK / 2
      ISTATE(J,1) = 7
      IF (IWRK .EQ. JWRK) ISTATE(J,1) = 6
  420 CONTINUE
      GO TO 475
C                                SYSTEM MUST BE BROUGHT UP
  450 DO 470 J=I,NTRUCK
      IF (JSTOP(J) .NE. 4) GO TO 470
      JSTOP(J) = 0
      JWRK = ISTATE(J,1)
      IF (JWRK .EQ. 0) ISTATE(J,I) = 2
      IF (JWRK .EQ. 1) ISTATE(J,1) = 3
  470 CONTINUE
  475 ISTOPT = 0
C                                APPLY DELTA-T TO ALL TRUCKS
  500 DO 750 I = I,NTRUCK
      DELTAC = 0.
      STATE(I,4) = STATE(I,4) + DTDAYS
      ISTAT=INT(STATE(I,1))
      TPOS = STATE(I,2)
      TSPD = STATE(I,3)


C                                          CRASH CODING
      ISTATO = ISTAT
      OTPOS = TPOS
      OTSPD = TSPD
C                                          END CRASH CODING
      IJSTOP = JSTOP(I)
      TEMSI = TEMS(I)
      TEMTI = TEMT(I)
      IWRK=ISTAT+1
      GO TO (510,750,550,570,590,610,630,650,750,750,750,750),IWRK
C                                TRUCK IS EMPTY, AND HAS STOPPED
  510 IF (IJSTOP .GT. I) GO TO 750
C                                TRUCK IS BEING LOADED
      LTRUCK = 1
      GO TO 750
C                                TRUCK IS ACCELERATING EMPTY
  550 IF (IOPTN - 1) 584,553,584
  551 AFA = PPA - FRWE
      IF (AFA .LT. 0.) AFA = 0.
      AE = AFA * WEC?
      IF (AE. GT. AEMAX) AE = AEMAX
      IF (DE .GT. 0.) GO TO 553
      TEMTI = TEMTI + DELTAT
      TEMSI = TEMSI + DT2640 * (AE * DELTAT + 2. * TSPD)
  553 YI = AE * DELTAT
      TPOS = TPOS + DT2640 * (YI + 2. * TSPD)
      TSPD = TSPD + YI
      IF (IOPTN .EQ. 2) HPEAH= (AE*WECI+FRWE) * TSPD/HPFAC
      IF (HPA .GT. 0. .AND. HPEAH .GT. HPA) HPEAH = HPA
      DELTAC = HPEAH
      IF (TSPD - VE) 558,554,554
  554 ISTAT = 4
```

```
      TSPD = VE
C                                 IS TRUCK APPROACHING FACE AREA
  558 IF (IOPTN .EQ. 1) GO TO 560
      IF (DE .GT. 0.) GO TO 560
      IF (2. * TPOS .GE. X) ISTAT = 6
C                                 CRASH CODING NEEDED WHEN DE/DF = 0 FIXED
      GO TO 698
  560 B = TSPD * TSPD * 2640. / DE
C                                                CRASH CODING
      XWRK = TPOS + B
      IF (XWRK .GE. X) ISTAT = 6
      IF (XWRK .GT. X .AND. ISTATO .EQ. 2) GO TO 565
C                                                END CRASH CODING
      GO TO 698
C                                                CRASH CODING
C                                 PREVENT TRUCK FROM CRASHING EMPTY
  565 XWRK=(DE*(AE*(X-OTPOS)+(2640.*OTSPD*OTSPD)))/(2640.*(DE+AE))
      IF (XWRK .LT. 0.) GO TO 698
      TSPDX = SQRT(XWRK)
      DTPP =(TSPDX - OTSPD) / AE
      TPOSX = OTPOS + (DTPP*2640.)*(AE*DTPP + 2.*OTSPD)
      IF (TPOSX .LT. OTPOS) GO TO 698
      DELTAC = HPEA * TSPDX / TSPD
      DTPPP = DELTAT - DTPP
      Y1 = DE * DTPPP
      TPOS = TPOSX + (2640. * DTPPP) * (2. * TSPDX - Y1)
      TSPD = TSPDX
      GO TO 632
C                                                END CRASH CODING
C                                 TRUCK IS ACCELERATING FULL
  570 IF (IOPTN - 1) 584,572,584
  571 AFA = HPA - FRFAC
      IF (AFA .LT. 0.) AFA = 0.
      AF = WFFAC1 * AFA
      IF (AF .GT. AFMAX) AF = AFMAX
      IF (DF .GT. 0.) GO TO 572
      TEMTI = TEMTI + DELTAT
      TEMSI = TEMSI + DT2640 * (AF*DELTAT + 2.*TSPD)
  572 Y1 = AF * DELTAT
      TPOS=TPOS-DELTAT*2640.*(Y1+2.*TSPD)
      TSPD = TSPD + Y1
      IF (IOPTN .EQ. 2) HPFAH= (AF*WFFAC2+FRFAC) * TSPD/HPFAC
      IF (HPA .GT. 0. .AND. HPFAH .GT. HPA) HPFAH = HPA
      DELTAC = HPFAH
      IF (TSPD - VF) 578,574,574
  574 ISTAT = 5
      TSPD = VF
C                                 IS TRUCK APPROACHING DISCHARGE POINT
  578 IF (IOPTN .EQ. 1) GO TO 580
      IF (DF .GT. 0.) GO TO 580
      IF (X - TPOS .LT. TPOS) GO TO 698
C                                 CRASH CODING NEEDED WHEN DE/DF = 0 FIXED
      ISTAT = 7
      TEMTI = TEMTI + (TSPD - VD) / TSPD
      ISW(I) = 100
      GO TO 698
  580 B = 2640. * (TSPD*TSPD - VDSQ) / DF
      IF (TPOS .GT. B) GO TO 698
      ISTAT = 7
      ISW(I) = 100
C                                                CRASH CODING
      IF (TPOS .LT. B .AND. ISTATO .EQ. 3) GO TO 582
C                                                END CRASH CODING
      GO TO 698
C                                                CRASH CODING
C                                 PREVENT TRUCK FROM CRASHING FULL
```

```
  582 XWRK=(DF*(AF*OTPOS+2640.*OTSPD*OTSPD)+2640.*AF*VOSQ) /
     *                (2640.*(DF+AF))
      IF (XWRK .LT. 0.) GO TO 698
      TSPDX = SQRT(XWRK)
      DTPP = (TSPDX - OTSPD) / AF
      TPOSX = OTPOS - (DTPP*2640.)*(AF*DTPP + 2.*OTSPD)
      IF (TPOSX .GT. OTPOS) GO TO 698
      DELTAC = HPFA * TSPDX / TSPD
      DTPPP = DELTAT - DTPP
      YI = DF * DTPPP
      TPOS = TPOSX - (2640. * DTPPP) * (2. * TSPDX - YI)
      TSPD = TSPDX
      GO TO 652
C                     END CRASH CODING
  584 RPA = TLIM
      IF (ISTAT .EQ. 3) RPA = TLIMF
      IF (HPA .EQ. 0.) GO TO 585
      YI = RPA
      IF (TSPD .GT. 0.) YI = HPAFAC / TSPD
      GO TO 589
  585 IF (TSPD .GT. TCURVX(1)) GO TO 586
      YI = TCURVY(1)
      GO TO 589
  586 DO 588 K=2,NPOINT
      XWRK = TCURVX(K)
      IF (XWRK .LT. TSPD) GO TO 588
      YWRK = TCURVY(K)
      YI = YWRK-((XWRK-TSPD)*(YWRK-TCURVY(K-1))/(XWRK-TCURVX(K-1)))
      GO TO 589
  588 CONTINUE
      YI = TCURVY(NPOINT)
  589 CONTINUE
      IF (YI .LT. RPA) RPA=YI
      IF (ISTAT-2) 571,551,571
C                                     TRUCK EMPTY, GOING AT FULL SPEED
  590 TPOS = TPOS + DTVEFT
      IF (IDPTN .EQ. 1) HPEVP = HPEV
      DELTAC = HPEVP
      GO TO 558
C                                     TRUCK FULL, GOING AT FULL SPEED
  610 TPOS = TPOS - DTVEFT
      IF (IDPTN .EQ. 1) HPFVP = HPFV
      DELTAC = HPFVP
      GO TO 578
C                                     TRUCK IS DECELERATING EMPTY
  630 IF (DE .EQ. 0.) GO TO 636
      YI = DE * DELTAT
      TPOS = TPOS + DT2640 * (2.*TSPD-YI)
  632 TSPD = TSPD - YI
      IF (TSPD .GT. 0.) GO TO 698
      ISTAT = 0
      TSPD = 0.
      TEMTI = 0.
      TEMSI = 0.
      IF (IJSTOP-4) 640,698,640
C                                     RIMPULL OPTION 2
  636 TEMTI = TEMTI - DELTAT
      IF (TEMTI .GT. 0.) GO TO 698
      ISTAT = 0
      TEMTI = 0.
      TSPD = 0.
      IF (IJSTOP .NE. 4) GO TO 640
      TPOS = TPOS + TEMSI
      TEMSI = 0.
      GO TO 698
C                                     TRUCK IN LOADING AREA
```

```
  640 TPOS = X
      IJSTOP = 1
      TEMSI = 0.
      GO TO 698
C                                    TRUCK IS DECELERATING FULL
  650 IF (DF .EQ. 0.) GO TO 654
      Y1 = DF * DELTAT
      TPOS = TPOS - DT2640 * (2.*TSPD - Y1)
  652 TSPD = TSPD - Y1
      IF (TSPD .LE. 0.) GO TO 658
      IF (ISW(I) .EQ. 100 .AND. TPOS .LE. 0.) GO TO 660
      GO TO 698
C                                    RIMPULL OPTION 2
  654 TEMTI = TEMTI - DELTAT
      IF (TEMTI .GT. 0.) GO TO 698
      IF (IJSTOP .EQ. 4) TPOS = TPOS + TEMSI
      IF (ISW(I) .EQ. 100) GO TO 660
  658 ISTAT = 1
      TSPD = 0.
      GO TO 662
  660 ISW(I) = 0
      ISTAT = 10
      TSPD = VD
      TPOS = 0.
  662 TEMTI = 0.
      TEMSI = 0.
  698 STATE(I,1)=ISTAT
      STATE(I,2) = TPOS
      STATE(I,3) = TSPD
      JSTOP(I) = IJSTOP
      TEMS(I) = TEMSI
      TEMT(I) = TEMTI
C                                    DEBUG PRINT
      IF (ISTATO .LT. 2 .OR. ISTATO .GT. 3) GO TO 700
C                                    END OF DEBUG PRINT
  700 DJMMH = DJMMH + (DELTAC * DTCPFC)
  750 CONTINUE
C
C                                    IS ANOTHER ITERATION REQUIRED FOR THIS DT
C
      NITER = NITER - 1
      IF (NITER) 900,900,360
C                                    UPDATE /NEWWRK/
  900 DO 920 J=1,NTRUCK
      FTSTAT(J,1)=STATE(J,1)
      FTSTAT(J,2) = STATE(J,2)
      FTSTAT(J,3) = STATE(J,3)
      FTSTAT(J,4) = STATE(J,4)
      LKSTOP(J) = JSTOP(J)
  920 CONTINUE
      LLSTOP = ISTOPT
  999 RETURN
      END
```

KK. SUBROUTINE TRNPRT(ICYCLE)

```
                SUBROUTINE TRNPRT(ICYCLE)
          C
          C     ELEMENT - MATERIALS HANDLING
          C     GENERAL PROCESS - CONVEYOR
          C     ACTIVITY - LONG HAUL MUCK TRANSPORT
          C     TECHNIQUE - TROUGH BELT CONVEYOR
          C
000003          COMMON/ALL/ XT,STR,IA,RQD,CS,TAMB,FLOW,IFLAG,AT,D,E,SK,T,DT,X,PR
               1,  XMAX,TMAX,TO,XO,XDISCH,DX
000003          COMMON/MONEY/ DJMMH
000003          COMMON/CONVEY/ ACM,DTBS,DWM,EE,FL,HP,QC,SMIN,WBI,
               1   WP,XLF,NSURGE,QE,QP,    DTCB,DTMB,AB,VBI,NEXON,NGEO,XE,LNSURG,
               2   STIME,QDMR,DTMI,DTMO,FLM,DMAINT
000003          COMMON/NEWCOM/ LMACON,LMCAPC,LNSPLC,LLOADR,FQL,LMKIN,LMUKOT,LNBYBY
000003          COMMON/OLDCOM/ MACON,MCAPC,NSPLIC,LOADR,QL,MKIN,MUKOT,NBYBY
000003          EQUIVALENCE (PR,PC),(XDE,XE)
000003          REAL LIR, LRR, LAM
000003          DIMENSION YKY(3)
000003          DIMENSION WB(11), VB(11), XIIR(11), XIRR(11), PLIES (11),QB(11)
000003          DATA XIIR/5., 4.5,4.,4.,4.,3.5,3.5,3.5,3.,3.,3./
000003          DATA XIRR/10,,10.,10.,10.,10.,10.,10.,10.,10.,8.,8./
000003          DATA PLIES/3.,4.,5.,6.,7.,8.,9.,10.,12.,12.,12./
000003          DATA QB/4., 4.5,5.7, 7.2, 9.6, 11.5, 14.2, 16.9, 19.4, 21.8, 24.3/
000003          DATA WB/18.,20.,24.,30.,36.,42.,48.,54.,60.,66.,72./
000003          DATA VB/300.,350.,400.,450.,500.,550.,600.,600.,600.,600.,600./
000003          DATA WPCOMP,AC,LIR,LRR,LAM,WR,X1 /7*0./
000003          DATA YKY /3*0./
000003          DATA ARG1,ARG2,ARG3,ARG4,HPS /5*0./
000003          DATA LIMIT,N,II,I /4*0/
          C     DETERMINE BELT CAPACITY
000003          IF (ICYCLE .GT. 1) GO TO 110
000006          ICYCLE=5
000006          IF (VBI .LE. 0.0) GO TO 20
          C     OPTION 1
000010          WPCOMP = 60./2000. * AB * VBI * CS/SK
000014          QP = 60.*AB*VBI
000015          DO 10 I=1,11
000017          IF (WBI .NE. WB(I)) GO TO 10
000021          II=I
000022          GO TO 90
000023       10 CONTINUE
000025          PRINT 11,WBI
000033       11 FORMAT ( 13H BELT WIDTH = ,F10.2, 15H IS NOT IN LIST)
000033          STOP
          C     DESIGN CONVEYOR OPTION 2
000035       20 DO 30 I = 1, 11
          C     SOLVE FOR WPCOMP (EST. PEAK TONNAGE COMPUTED) THAT MATCHES OR IS
          C     GREATER THAN WP (EST.PEAK TONNAGE INPUTTED)
000040          AB= (1./144.)*(0.1247*WB(I)*WB(I) - 0.8245*WB(I) +1.311)
000046          WPCOMP=60./2000.*AB*VB(I)*CS/SK
000053          IF (WPCOMP .LT. WP) GO TO 30
000055          II=I
000057          VBI=VB(I)
000060          WBI=WB(I)
000062          QP=60.*AB*VBI
000064          GO TO 50
000065       30 CONTINUE
```

```
   35 PRINT 40
   40 FORMAT (109H CONVEYOR DESIGN CAN NOT BE FOUND FOR GIVEN PEAK TONAG
     1E AND MAXIMUM TOTAL CROSS SECTION OF STRUCTURE)
      STOP
C     CHECK FOR MAX. TOTAL CROSS SECTION OF CONVEYOR STRUCTURE
   50 AC=10.84+ .357*WB1 - .00203*WB1*WB1 + .000414*WB1*WB1*WB1
      IF (AC .GT. ACM) GO TO 35
C     SELECT IDLER ROLLER AND ROLLER SPACING
C     II IS THE SUBSCRIPT OF THE BELT WIDTH BEING USED
   90 LIR = XIIR (II)
      LRR=XIRR(II)
      LAM =.00068*(QB(II)+100.*AB)+2.13/LIR+ .035*QR(II)
     1          +2.*AB
      IF(XLF .NE. 0.) GO TO 110
      XLF = PLIES(II) *55.*WB1/(1.62*LAM) - 500./LAM
C     COMPARE CONVEYOR CAPACITY WITH THAT REQUIRED FOR GIVEN ADVANCE RATE
C     COMPUTE REQUIRED CAPACITY
  110 WR=(1./2000.)*QL*CS/SK
      PRINT 200,WRCOMP,WR
  200 FORMAT(60X,2F10.2)
      IF(WRCOMP-WR) 130,120,125
  120 LMCAPC= 0
      GO TO 160
  125 LMCAPC = 0
      GO TO 150
C     CAPACITY OF CONVEYOR EXCEEDED
C     IS THERE A SURGE BIN TO HOLD EXCESS MUCK
  130 IF (NSURGE .EQ. 1) GO TO 140
C     CASE 1 - NO SURGE BIN
C     TURN OFF EXCAVATOR ON NEXT CYCLE
      LMCAPC = 1
  134 PRINT 135, X,DT,WR,WRCOMP,WB1,VB1,AB
  135 FORMAT (33H1CONVEYOR CAPACITY EXCEEDED AT X=, F10.2,10H AND TIME=,
     1  F10.2/10X,18H TONS/HR REQUIRED =, F10.3/10X,18H TONS/HR PROVIDED=,
     2   F10.2/10X,12H BELT WIDTH=, F10.3/10X,12H BELT SPEED=,F10.2/
     310X,20H FLOW CROSS SECTION=,F10.2/)
      GO TO 150
C     CASE 2 - SURGE BIN HAS BEEN PROVIDED
  140 QE= (QL - QP) *DT
      CALL SURGE
      IF (LMSURG .NE. 1) GO TO 160
C     IF CAPACITY HAS BEEN EXCEEDED THEN STOP EXCAVATOR IN NEXT CYCLE
      LMCAPC = 1
      GO TO 134
C     FOR A SYSTEM CONTAINING A SURGE BIN IT MAY BE NECESSARY TO
C     SUBTRACT MUCK FROM THE BIN WHEN WRCOMP  IS GREATER THAN WR
  150 QE=(QP-QL)*DT
      CALL SURGE2
C     MOTOR SHAFT HORSEPOWER
C     FOR OPTION 2 - HP MUST BE DERIVED
  160 IF (HP.GT.0.0) GO TO 180
      N=X/XLF
C     THERE ARE TWO EQUATIONS FOR HP.  ONE FOR N=0.  ONE FOR N GREATER
C     THAN 0.
C     X1 IS THE LAMBDA (FT) WHICH IS DESCRIBED IN THE WRITEUP.  IT CAN
C     BE X, XLF, OR X-XLF.FOR X1=X, I IS SET TO 1.   FOR X1=XLF,
C     I IS SET TO 2.  FOR X1=X-XLF, I IS SET TO 3.  YKY IS KY IN THE
C     DOCUMENTATION.
```

```
      IF (N.GT.0) GO TO 157
      I=1
      LIMIT=2
      X1=X
      GO TO 159
  157 LIMIT=1
      I=2
      X1=XLF
      GO TO 159
  158 LIMIT=2
      I=3
      X1=X-XLF
  159 IF (X1 .GT. 800.) GO TO 161
      YKY(I)= .035
      GO TO 168
  161 IF (X1 .GT. 1000.) GO TO 162
      YKY(I)=.032
      GO TO 168
  162 IF(X1.GT. 1400.) GO TO 163
      YKY(I)= .030
      GO TO 168
  163 IF (X1 .GT. 2000.) GO TO 164
      YKY(I)= .024
      GO TO 168
  164 IF (X1 .GT. 2500.) GO TO 165
      YKY(I)= .020
      GO TO 168
  165 IF (X1 .GT. 3000.) GO TO 166
      YKY(I)= .019
      GO TO 168
  166 YKY(I)= .018
  168 IF (LIMIT .NE. 2) GO TO 158
      ARG1 = VBI/33000.
      ARG2= .000682 (OR(II) +100. *AB) +2.13/LIR
      ARG3=WPCOMP/990.
      ARG4= ARG1*550.
      IF (N .GT. 0) GO TO 170
      HPS=X*ARG1*(ARG2+(YKY(1)+.015)*OR(II))+ARG3*YKY(1)*X+ARG4
      GO TO 175
  170 HPS= N*(XLF*ARG1*(ARG2+(YKY(2)+.015) *OR(II)) + YKY(2)*
     1       ARG3*XLF + ARG4) +
     2     (X-N*XLF)*ARG1*(ARG2+(YKY(3)+ .015)*OR(II)) + YKY(3)*
     3     (X-N*XLF)*ARG3+ARG4
C     OPTION 2 - E MAY BE SPECIFIED
      IF (EE .LE. 0.0) EE=0.76
  175 DJMMH=PC*HPS*0.746*DT/EE +DJMMH
      RETURN
C     OPTION 1 - HP AND E MUST BE SPECIFIED
  180 IF (EE.LE. 0.)EE=0.76
      DJMMH= PC*HP*X*0.746*DT/EE +DJMMH
      RETURN
      END
```

LL. SUBROUTINE EXTNSN(ICYCLE)

```
                SUBROUTINE EXTNSN(ICYCLE)
          C
          C     ELEMENT - MATERIALS HANDLING
          C     GENERAL PROCESS - LONG HAUL CONVEYOR BELT
          C     ACTIVITY - EXTENSION OF THE BELT
          C
000003          COMMON/ALL/ XT,STR,IA,RQD,CS,TAMB,FLOW,IFLAG,AT,D,E,SK,T,DT,X,PR
               1,  XMAX,TMAX,TO,XO,XDISCH,DX
000003          COMMON/MONEY/ DJMMH
000003          COMMON/CONVEY/ ACM,DTBS,DWM,EF,FL,HP,QC,SMIN,WBI,
               1   WP,XLF,NSURGE,QE,QP,    DTCR,DTMB,AB,VBI,NEXON,NGEO,XE,LNSURG,
               2   STIME,QDMR,DIMI,DTMO,FLM,DMAINT
000003          COMMON/NEWCOM/ LMACON,LMCAPC,LNSPLC,LLOADR,FQL,LMKIN,LMUKOT,LNBYBY
               1,  FSM
000003          COMMON/OLDCOM/ MACON,MCAPC,NSPLIC,LOADR,QL,MKIN,MUKOT,NBYBY,SM
000003          DATA T/0./,DTE2/0./,DTBS2/0./
000003          DATA DTE /0./
000003          DATA FLA,FLS,S /3*0./
000003          IF (ICYCLE .GT.1) GO TO 30
000006          ICYCLE = 5
000006          GO TO (1,2,3),NGEO
          C     GEOMETRY 1 - ASSUME FLA EXTENDS THE FULL LENGTH OF CONVEYOR
000015        1 FLA = FL
000016          FLS = 0.
000017          X = FL
000021          GO TO 10
          C     GEOMETRY 2 - ASSUME FEEDER CONVEYOR EXTENSION IS SMALL (FL=0)
          C     AND EMPTIES INTO SHAFT DIRECTLY
000021        2 FLA = 0.
000022          FLS = 0.
000023          GO TO 10
          C     GEOMETRY 3
000023        3 FLS = 0.
000024          SM = SMIN
          C     DETERMINE CONVEYOR STRUCTURE EXTENSION PARAMETERS
          C     OPTION1 - XE,DTBS INPUT
          C     OPTION 2 - XE = F (WB,LIR)
          C     OPTION 2 - DTBS =
000026       10 CONTINUE
          C     NORMAL ENTRY POINT AFTER FIRST CALL - INCREMENT DT
          C     IS EXTENSION SHUT DOWN
000026       30 IF (NEXON .EQ. 1) RETURN
          C     BELT SPLICE OR STRUC. EXTENSION
000031          PRINT 501,FLA,FLS
000041      501 FORMAT(96X,2F10.2)
000041          IF(NSPLIC .EQ. 0) GO TO 31
000043          IF(LNSURG .EQ. 1) GO TO 112
000045          GO TO 122
          C     CONVEYOR STRUCTURE ONLY
000046       31 IF (NGEO .NE. 3) GO TO 40
          C     GEOMETRY 3 - CYCLIC OPER.
000050          IF  (DTE .NE. 0.0) GO TO 32
000051          DTE = DX/XE
000053       32 DTE = DTE - DT
          C     UPDATE CONVEYOR STR. COMPLETED
000055          FLS = FLS + DX
000057          IF (DTE .GT. 0.)  GO TO 33
```

```
      LNBYBY = 0
      DTE = 0.
      GO TO 100
   33 LNBYBY = 1
      GO TO 100
C     GEOMETRY 1 + 2 - CONTINUOUS OPERATIONS
C     CONVEYOR STRUCT. COMPLETED IN DT
   40 FLS = FLS + XE*DT
C     AVAILABLE CONVEYOR AFTER DT
      IF (NGEO .NE. 1) GO TO 45
      FLA = FLA - DX
      GO TO 60
   45 FLA = 0.
      FL = FL + DX
C     CHECK TO SEE IF CONVEYOR EXTENSION HAS CAUGHT UP TO EXCAVATOR
   60 S = FL - FLS - FLA
      IF(S .GT. 0.) GO TO 80
C     CONVEYOR EXTENSION HAS CAUGHT UP.  LET ADVANCE OF CONVEYOR
C     EQUAL EXCAVATOR FOR THIS DT.
      FLS = FLS -DT*XE + DX
      GO TO 100
C     CHECK TO SEE IF FEEDER RUNAWAY TOLERANCE IS EXCEEDED
   80 IF ( S .GE. SM) GO TO 90
      LNBYBY = 0
      GO TO 100
C     EXCEEDED - THEREFORE TURN OFFEXCAVATOR NEXT DT
   90 LNBYBY = 1
C     CHECK TO SEE IF BELT SPLICE NEEDED
  100 GO  TO (105,106,107), NGEO
C     BELT SPLICE NOT NEEDED
  101 LNSPLC = 0
      RETURN
  105 IF (FLA .GT. 0.) GO TO 101
      GO TO 109
  106 IF(FL .LT. FLM) GO TO 101
      GO TO 109
  107 IF  (S .LT. SM) GO TO 101
C     SPLICE NEEDED
  109 LNSPLC = 1
      IF (NSURGE .EQ. 1)  GO TO 118
      IF (NGEO .EQ. 3) GO TO 111
C     ARE THERE SURGE BINS TO HOLD MUCK DURING SPLICE
C     CASE I - NO SURGE BINS (NSURGE = 0)
C     LET CONVEYOR STRUCTURE CATCH UP TO EXCAVATOR AND SPLICE BELT
  110 DTE  = (FL - FLA -FLS ) /XE  + DTBS
      GO TO 112
  111 DTE  =  DTBS
C     TURN OFF EXCAVATOR UNTIL THIS IS COMPLETED
  112 DTE2 = DTE2 + DT
      IF(DTE2 .GE. DTE) GO TO 113
      LNSPLC = 1
      RETURN
C     SPLICE COMPLETED - REINITIALIZE
  113 LNSPLC = 0
      GO TO (114,115,116), NGEO
  114 FLA=0.
      DTE2 = 0.
      RETURN
```

```
  115 FL = 0.
      DTE2 = 0.
      RETURN
  116 FSM= SMIN
      DTE2 = 0.
      FLS = 0.
      RETURN
C     CASE 2 - SURGE BIN HAS BEEN PROVIDED - (NSURGE = 1)
  118 QF = (QL - QP)*DT
      CALL SURGE
      IF (LNSURG .EQ. 1) GO TO 130
      IF (DTBS2 .NE. 0.) GO TO 122
      DTBS2 = DTBS
  122 DTBS2 = DTBS2 - DT
      LNSPLC = 0
      IF (DTBS2 .GT. 0.) RETURN
C     SPLICE COMPLETED - REINITIALIZE
      GO TO (123,124,125) ,NGEO
  123 FLA = FLS
      RETURN
  124 FL = FL - FLS
      RETURN
  125 FSM= SMIN
      FLS = 0.
      RETURN
C     IF SUBROUTINE SURGE RETURNS WITH A FLAG INDICATING CAPACITY
C     OF SURGE BIN HAS BEEN EXCEEDED (LNSURG=1) DURING DT, THAN TREAT
C     AS IF THERE IS NO SURGE BIN
  130 DTBS = DTBS2
      GO TO ( 110,110,111 ),  NGEO
      END
```

MM. SUBROUTINE SURGE

```
      SUBROUTINE SURGE
C     TWO ENTRY POINTS INTO THIS SUBROUTINE
C     ENTRY SURGE - TO PUT MUCK INTO BIN
C     ENTRY SURGE2 - TO TAKE MUCKOUT
C
C     ELEMENT - MATERIALS HANDLING
C     GENERAL PROCESS - LONG HAUL CONVEYOR BELT
C     ACTIVITY - LOADING EXCESS MUCK INTO SURGE BIN OR UNLOADING FROM BIN
C
      COMMON/ALL/ XT,STR,IA,ROD,CS,TAMB,FLOW,IFLAG,AT,D,F,SK,T,DT,X,PR
     1,  XMAX,TMAX,TO,XO,XDISCH,DX
      COMMON/MONEY/ DUMMH
      COMMON/CONVEY/ ACM,DTBS,D,M,FF,FL,HP,QC,SMIN,WBI,
     1   WP,XLF,NSURGE,QE,QP,    DTCR,DTMR,AB,VBI,NEXON,NGEO,XE,LNSURG,
     2   STIME,QDMR,DTMI,DTMO,FLM,DMAINT
      COMMON/NEWCOM/ LMACON,LMCAPC,LNSPLC,LLOADR,FOL,LMKIN,LMUKOT,LNBYBY
      COMMON/OLDCOM/ MACON,MCAPC,NSPLIC,LOADR,OL,MKIN,MUKOT,NBYBY
      EQUIVALENCE (PR,PC),(XDE,XE)
      DATA Q/0./
C     ENTRY SURGE
      IF(LNSURG .EQ. 1) RETURN
      Q=Q+QE
      IF (Q .GT. QC) GO TO 10
      LNSURG = 0
      RETURN
   10 LNSURG = 1
      RETURN
C
      ENTRY SURGE2
      Q=Q-QE
      IF (Q .GT. 0.) RETURN
      Q= 0.0
      RETURN
      END
```

NN. SUBROUTINE BELT(ICYCLE)

```
                    SUBROUTINE BELT(ICYCLE)
              C
              C     ELEMENT - MATERIALS HANDLING
              C     GENERAL PROCESS - LONG HAUL CONVEYOR BELT
              C     ACTIVITY - MAINTENANCE OF BELT
              C
000003              COMMON/ALL/ XT,STR,IA,RQD,CS,TAMB,FLOW,IFLAG,AT,D,E,SK,T,DT,X,PR
                   1,  XMAX,TMAX,TO,XO,XDISCH,DX
000003              COMMON/MONEY/ DJMMH
000003              COMMON/CONVEY/ ACM,DTBS,DWM,EE,FL,HP,QC,SMIN,WBI,
                   1   WP,XLF,NSURGE,QE,QP,    DTCB,DTMB,AB,VBI,NEXON,NGEO,XE,LNSURG,
                   2   STIME,QDMR,DTMI,DTMO,FLM,DMAINT
000003              COMMON/NEWCOM/ LMACON,LMCAPC,LNSPLC,LLOADR,FQL,LMKIN,LMUKOT,LNBYBY
000003              COMMON/OLDCOM/ MACON,MCAPC,NSPLIC,LOADR,QL,MKIN,MUKOT,NBYBY
000003              EQUIVALENCE (PR,PC),(XDE,XE)
000003              DATA PI/3.141592/
000003              DATA W,TM,T /3*0./
              C     INITIALIZE PARAMETERS
000003              IF (ICYCLE .NE. 1) GO TO 10
000005              ICYCLE = 10
000006              W=0.
              C     DWM MUST HAVE A DEFAULT VALUE SPECIFIED.  SET=1. FOR COMPILATION
000006              IF (DWM .LE. 0.) DWM=1.
000011              TM=0.
000012              TT=DTMB
000014           10 IF (MACON .EQ. 1) GO TO 30
000016              IF(DTCB .EQ. 0.) GO TO 20
000017              TM = TM + DT
000021              IF(DTCB .GT. TM) GO TO 15
000024              LMACON = 1
000025              TM = 0.
000025              GO TO 30
000026           15 LMACON = 0
000027              RETURN
              C     TONAGE OF MUCK CRITERIA SPECIFED
000030           20 W=(PI*D*D/4.)/2000. *CS *DX +W
000037              IF (W .GE. DWM) GO TO 25
000041              LMACON = 0
000042              RETURN
000042           25 LMACON = 1
000043              W = 0.
              C     TIMEKEEPER ON MAINTENANCE
000044           30 TT=TT-DT
000046              IF(TT .LE. 0) GO TO 40
000047              LMACON = 1
000050              RETURN
000051           40 LMACON = 0
              C     DMAINT NEEDS A VALUE IF IT HAS NOT BEEN SPECIFIED,
              C     DMAINT SET =1. FOR COMPILATION
000052              IF (DMAINT .LE. 0.) DMAINT =1.
000055              DJMMH = DJMMH + DMAINT
000057              RETURN
000057              END
*FOLLOWING VARIABLES EQUIVALENCED BUT NOT REFERENCED
PC
XE
PR
```

OO. SUBROUTINE XXXMNT (General Maintenance Routine to Be Adapted by User for Specific Processes)

```
      SUBROUTINE XXXMNT
C
C     ELEMENT -
C     GENERAL PROCESS -
C     ACTIVITY - GENERAL MAINTENANCE + REPAIR
C
      COMMON /
      DATA TRET,TMNT /2*0./
      DATA INIT,NEEDIN /2*0/
C
C                                 EQUIVALENCE FOR SPECIFIC GENERAL PROCESS
      EQUIVALENCE (GDTC,          )
      EQUIVALENCE (GDTM,          )
      EQUIVALENCE (GDJM,         )
      EQUIVALENCE (DJMGP,       )
      EQUIVALENCE (MMNT,            )
      EQUIVALENCE (LMMNT,       )
      EQUIVALENCE (MFLAG,         )
      EQUIVALENCE (LMFLAG,        )
C
C
C                                 INITIALIZATION
   10 TRET = GDTC
      MMNT = 1
      IF (GDTC .EQ. 0.) GDTC =
      IF (GDTM .EQ. 0.) GDTM =
      IF (GDJM = 0.) GDJM =
      INIT = 1
      IF (NEEDIN = 0) GO TO 999
      NEEDIN = 0
      GO TO 200
C
C                                 NORMAL ENTRY
      ENTRY XXXRPR
      IF (INIT .EQ. 1) GO TO 200
      NEEDIN = 1
      GO TO 10
C                                 IS MAINTENANCE IN PROGRESS
  200 IF (MMNT .EQ. 0) GO TO 400
C                                 IS MAINTENANCE REQUIRED
      TRET = TRET - DT
      IF (TRET .GT. 0.) GO TO 999
C        DOES ANY OTHER SITUATION EXIST SUCH THAT MAINTENANCE SHOULD
C              NOT BE PERMITTED. IF SO, GO TO 999
      LMMNT = 0
      LMFLAG = LMFLAG + 1
      GO TO 999
C                                 UPDATE PROGRESS OF MAINTENANCE
  400 TMNT = TMNT + DT
C                                 IS MAINTENANCE COMPLETED
      IF (TMNT .LT. GDTM) GO TO 999
      DJMGP = DJMGP + GDJM
      TRET = GDTC
      TMNT = 0.
      LMMNT = 1
      LMFLAG = LMFLAG - 1
  999 RETURN
C     NOTE -- CHECK TESTING OF MFLAG IN RELATED SUBROUTINES
      END
```